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Developing Teachers' Contextual Knowledge and TPACK in a Pedagogical Change Laboratory

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INTRODUCTION

In the pursuit of effective technology integration, teachers should engage in the interplay of diverse knowledge related to technology, pedagogy, and disciplinary content while taking into account their specific context, namely the contextual factors unique to their educational environment (Brianza et al., 2022; Mishra & Warr, 2021). The Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006; Mishra et al., 2023; Zhang & Tang, 2021) addresses the intersections of technology, pedagogy, and content required for effectively developing technology-enhanced learning activities (TEL) within the complex context in which teaching and learning take place (Koehler & Mishra, 2009; Rosenberg & Koehler, 2015). The learning by design (LBD) approach (Koehler, 2005; Koehler & Mishra, 2005; Koehler et al., 2007) is widely recognized and used to foster teachers' development of TPACK (Phillips, 2016; Voogt et al., 2016; Warr & Mishra, 2023; Yeh et al., 2021). In LBD, teachers are expected to actively learn to blend their understanding of technology, teaching methods, and subject matter in order to create meaningful and engaging learning experiences in ways that are appropriate to the specific parameters of their context (Koehler & Mishra, 2008). Though context has been described as a core element of the framework (Angeli & Valanides, 2005, 2009; Harris & Hofer, 2017; Mishra & Koehler, 2006; Porras-Hernández & Salinas-Amescua, 2013), it appears to remain an under- and discordantly represented construct in TPACK research (Brianza et al., 2022; Rosenberg & Koehler, 2015). According to Mishra (2019), this is due to a semantic inconsistency in the canonical TPACK diagram, which he proposes to address by upgrading context to contextual knowledge (XK). XK is teachers' knowledge of the context that they "must possess to integrate technology in teaching" from "awareness of available technologies", to "knowledge of the school, district, state, or national policies they operate within" (p. 76).

From an interventionist perspective (Gutiérrez et al., 2016), we consider that XK is not only something to be studied in TPACK research but "something that we (as teacher educators) can act on, change, and help teachers develop" (Mishra, 2019, p. 76). Our purpose is to investigate how in-service teachers can develop their XK through a teacher training intervention using the synergistic approaches of expansive learning (Engeström, 2015) and LBD (Koehler & Mishra, 2005; Voogt et al., 2015). To this end, we developed a formative intervention (Virkkunen & Newnham, 2013), derived from the Change Laboratory

interventions (Sannino & Engeström, 2017), and situated within the cultural-historical activity theory (CHAT) perspective. This intervention, called the pedagogical change laboratory (PCL), consists of a two-and-a-half-day workshop that assists teachers in co-designing new TEL scenarios (Duret & Romero, 2022) to transform their activity systems and change their practices. Taking expansive learning actions (Engeström, 2015; Sannino & Engeström, 2017), teachers examine their educational context from a systemic perspective to identify the pedagogical and didactic challenges that the TEL scenarios will aim to address. A central premise of our approach is that the co-design of TEL scenarios, as an element incorporated into an expansive learning cycle, supports LBD and assists teachers in developing their XK and TPACK.

This chapter aims to study how teachers mobilize their XK during the PCL. It is divided into three main sections. Adopting a conceptual perspective, we first present the formative intervention we designed by combining CHAT interventionist methodology and the LBD approach. It is followed by an empirical analysis of the XK mobilized by teachers in the PCL. In the final section, we discuss the findings and highlight the most important ones, some of which have specific implications for teacher education research and practice.

PEDAGOGICAL CHANGE LABORATORY AS AN XTPACK INTERVENTION

This section outlines the conceptual underpinnings that have guided the design of the PCL as a TPACK professional development intervention. We first discuss expansive learning in connection with LBD to achieve this objective. Then, we expose how we have adapted the traditional Change Laboratory to turn it into a formative intervention likely to support teachers' contextual knowledge (XK) and TPACK. Finally, we discuss the challenge of grasping the intricacy of XK in the context of the teachers' learning design activity, as well as how cultural-historical activity theory (CHAT) is likely to provide a conceptual and methodological framework for both analysis and development of XK.

Combining Expansive Learning and Learning by Design

Integration of digital technology and practices into teaching and learning is a complex and ongoing process of systemic change (Hauge, 2016; Kirschner, 2015; Pettersson, 2021; Reinius et al., 2022; Scherer et al., 2019; Timotheou et al., 2023). It both necessitates and results in the transformation of the teaching-learning activity (Laferrière et al., 2013; Lund & Hauge, 2011; Ritella & Hakkarainen, 2012; Virkkunen, 2006; Virkkunen & Newnham, 2013). However, "teacher change cannot be achieved merely through direct instruction" (Koehler & Mishra, 2005, p. 99). Indeed, when it comes to transforming activity systems, "traditional modes of learning are not enough" because "nobody knows exactly what needs to be learned" (Engeström & Sannino, 2010, p. 3). In other words, if teachers have to learn how to transform their activity system and practices, it is not a question of dealing with "tasks in which the contents to be learned are well known ahead of time" (Rantavuori et al., 2016, p. 3). It is about creating new knowledge and new practices adapted to their specific context.

Expansive learning (Engeström, 2015) offers a response to this kind of challenge. It is a type of learning in which learners "construct a new object and concept for their collective

activity and implement this new object and concept in practice" (Engeström & Sannino, 2010, p. 2). It relies on an expansive visibilization process (Engeström, 2018), which consists of "making troubles, contradictions, future visions, and novel solutions [...] visible, so that the practitioners could transform their activity in conceptually mastered and practical" (p. 198). It proposes seven steps consisting of epistemic actions: questioning, analyzing, modeling, examining, implementing, reflecting, and consolidating. The goal is to make systemic tensions and contradictions visible so that participants can not only make sense of the disturbances they experience in their daily practices but also commit to transforming their activity system by identifying the future direction they wish to take. These expansive learning actions, based on a systemic approach, offer teachers the opportunity to "navigate the necessarily complex interplay between tools, artifacts, individuals, and contexts" (p. 99), which Koehler and Mishra (2005) call for through the LBD approach. Indeed, by visibilizing the salient elements of their activity system in order to redesign it, teachers are actively encouraged to mobilize and develop their XK, which can be fruitfully used to inform their decisions when co-designing new TEL scenarios.

Based on these prior points, we consider the potential of linking these two approaches—expansive learning and LBD—as an avenue for developing teachers' XK and TPACK. This is what we propose in the PCL, a formative intervention based on the Change Laboratory (CL) methodology.

From Change Laboratory to Pedagogical Change Laboratory

The theory of expansive learning is at the heart of a formative intervention toolkit called the Change Laboratory (Engeström, 2020; Engeström et al., 2013), an interventionist approach conducted within the framework of CHAT (Virkkunen & Newnham, 2013). With the support of the researcher-interventionist, participants are encouraged to collectively confront their problematic conditions and break away from them by designing a new concept for their activity system that is not known in advance by the researcher (Engeström, 2011; Virkkunen & Newnham, 2013) and that they implement in practice (Engeström & Sannino, 2010; Hopwood & Sannino, 2023). The CL typically consists of five to ten consecutive two-hour sessions, often with follow-up sessions scheduled after several months (Engeström, 2011). CL methodology (Virkkunen & Newnham, 2013) has an interesting point of convergence with the LBD approach (Koehler, 2005; Koehler & Mishra, 2005; Koehler et al., 2007). They are both defined as a collective endeavor where participants, i.e., teachers, collaboratively focus on authentic problems of practice (Koehler & Mishra, 2005; Mishra & Koehler, 2003; Yeh et al., 2021). This prompted us to combine these two approaches into the formative intervention we called the PCL.

The PCL is based on the same epistemological principles as the CL. It uses the principle of double stimulation, a mechanism to intentionally overcome a conflicting situation, and the theory of expansive learning (Engeström, 2020; Sannino & Engeström, 2017). It engages teachers in a process of recognizing and analyzing their problematic situation with the aim of breaking out of it and concretely changing their practices. The PCL is a variation of the CL (Engeström, 2011) that does not strictly replicate the traditional methodology. On the one hand, it proposes a different time format in order to better fit the ecological requirements of in-service teachers. Additionally, which is of

particular interest in this study, unlike the traditional CL, the PCL has been specifically designed so that teachers can take full advantage of the digital technologies available in their environment. By combining the LBD approach with double stimulation and expansive learning, the PCL enables teachers to co-design new TEL scenarios based on a systemic analysis of their activity system, with the aim of transforming their practices. In other words, mobilizing CHAT methodology is intended to foster both contextual analysis (Nguyen et al., 2022) and intentional change (Mishra & Warr, 2021) within an LBD approach.

Learning Design and Contextual Knowledge Within a Chat Perspective

Learning design is a complex activity that has been studied from a diversity of epistemological and methodological perspectives (Duret & Romero, 2022; Koehler, 2005; Laurillard et al., 2013; Maina et al., 2015; Schön, 1987; Tricot & Musial, 2020). One of the most significant challenges in learning design is the complexity that arises from the incorporation of contextual factors (Mishra & Warr, 2021). Indeed, learning design goes beyond mere generic instances of the prescribed curriculum to tailor learning activities to the needs of the learners within a given context. In this regard, we note the choice of the acronym XK to represent teachers' contextual knowledge in TPACK (Mishra, 2019). As the author indicates, contextual knowledge is highly variable, making the letter X especially suitable. The five spaces for design in education (Mishra & Warr, 2021)—artifacts, processes, experiences, systems, and culture—emphasize the importance of teachers designing from a broad systemic perspective and highlight how critical it is to articulate different levels of contextual knowledge in TEL design. The key aspect in TEL design is teachers' coordinated mobilization of TPACK and XK. Therefore, it is crucial that teachers are empowered to effectively mobilize their contextual knowledge in TPACK professional development.

CHAT, which provides methodological tools for systemic analysis and transformation, offers teachers the opportunity to transform their practices by drawing on their contextual knowledge. In CHAT, "activity itself is the context" (Nardi, 1996, p. 73), and human actions exist only in relation to the context (Postholm, 2015). Adopting this perspective, teaching|learning activity is a complex system that "weaves together its own dynamic context" (Engeström & Sannino, 2021, p. 2) and involves multiple interacting components, including digital technologies (Figure 4.1).

To us, it seems that adopting a CHAT perspective in TEL design is well-aligned with Koehler and Mishra's view of TPACK, who highlight the fact that "teachers constantly negotiate a balance between technology, pedagogy, and content in ways that are appropriate to the specific parameters of an ever-changing educational context [emphasis added]" (Koehler & Mishra, 2008, p. 21). To fully enact TPACK, which does not exist in a vacuum (Mishra & Warr, 2021), teachers should be effectively encouraged to draw on their contextual knowledge (Mishra, 2019). We assume that one way to accomplish this could be to help teachers take into account their activity system as a complex whole context within which their actions are embedded. From this standpoint, our approach appears to be consistent with Brianza et al.'s view of XK (2022). Drawing upon the findings of their systematic literature review, they propose to define contextual knowledge as the teacher's understanding of the factors co-occurring at different levels and dimensions and "of how they reciprocally influence each other within
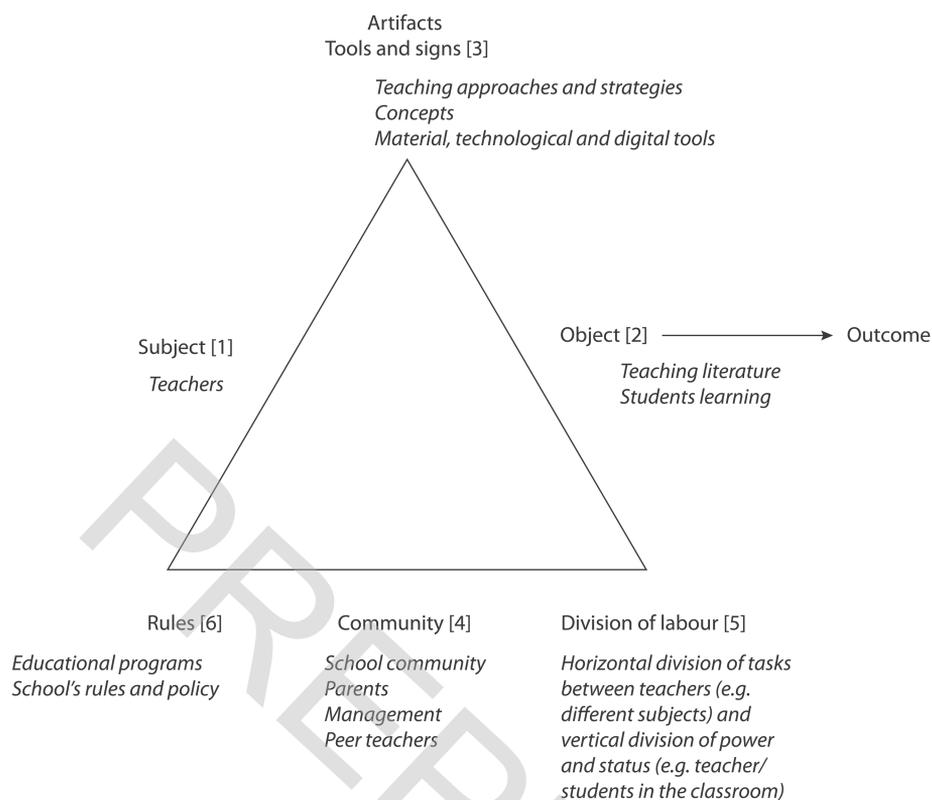
Artifacts
Tools and signs [3]

Teaching approaches and strategies
Concepts
Material, technological and digital tools

Subject [1]

Teachers

Object [2] ⟶ Outcome

Teaching literature
Students learning

Rules [6]

Educational programs
School's rules and policy

Community [4]

School community
Parents
Management
Peer teachers

Division of labour [5]

Horizontal division of tasks
between teachers (e.g.
different subjects) and
vertical division of power
and status (e.g. teacher/
students in the classroom)

FIGURE 4.1
The model of human activity adapted to our study of teachers' activity systems, based on Engeström and Sannino (2010).

Note: "Subject [1] refers to the individual or subgroup whose position and point of view are chosen as the perspective of the analysis. Object [2] refers to the 'raw material' or 'problem space' at which the activity is directed. The object is turned into outcomes with the help of instruments, that is, tools and signs [3]. Community [4] comprises individuals and subgroups who share the same general object. Division of labor [5] refers to the horizontal division of tasks and the vertical division of power and status. Finally, rules [6] refer to the explicit and implicit regulations, norms, conventions, and standards that constrain actions within the activity system" (Engeström & Sannino, 2010, p. 6).

this shared setting" (p. 731). This leads us to draw parallels between the two frameworks, i.e., between the ConteXTPACK framework (Brianza et al., 2022), as shown in Figure 4.2, and the Activity Theory Framework (Figure 4.1). Analyzing the ConteXTPACK (XTPACK) with a systemic cultural-historical lens reveals that most of the contextual elements identified by Brianza et al. (2022) can be associated with components of the activity system triangle (Figure 4.3). The transposition of the XTPACK elements into the activity theory model allows us to observe how the XTPACK can be instantiated as a dynamic activity system. Studying XTPACK and XK through the CHAT perspective aligns with Mishra and Warr's (2021) view, which highlights the significant advantages for teachers in comprehending broader systemic and cultural influences and their mechanisms. Having this comprehension allows teachers to leverage these dynamics effectively for their own and their students' benefit. This view is closely related to that of the PCL.
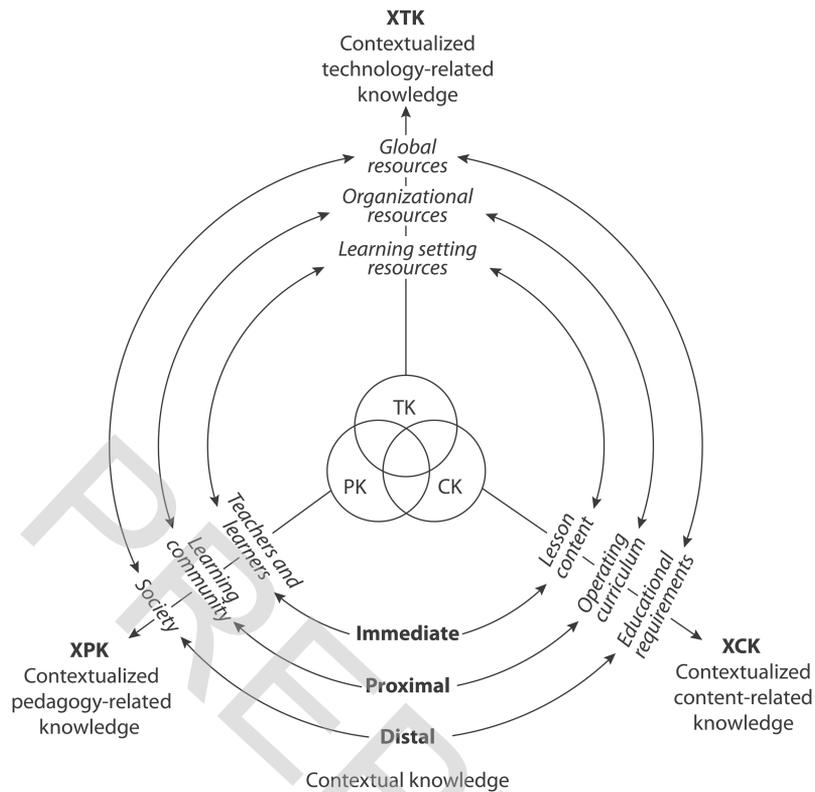
FIGURE 4.2
Networked contextual and contextualized knowledge forming XTPACK (Brianza et al., 2022, p. 730).

Designing a Formative Intervention Based on XTPACK

Teachers' TPACK professional development should be highly "related to the socio-cultural context of teaching and learning, embracing the educational setting as a situated complex activity system" (Augustsson, 2020, p. 20). The PCL is then to be considered a collective XTPACK professional learning and development where teachers are invited to focus on historical and contextual factors that shape their activity system (Kajamaa and Hyrkkö, 2022). The goal is that teachers recognize their actual pedagogical problems and conceptualize them as stemming from systemic contradictions in order to break away from their problematic situation. Teachers are engaged in a creative, collaborative problem-solving process through a set of learning actions, including co-designing new TEL scenarios. In the PCL, teachers are put in a "role of generating knowledge, not just consuming it" (Koehler and Mishra, 2005, p. 99) because they are involved in a creative and transformative process of both modeling a new concept for their activity system and LBD how to integrate digital technology and practices into teaching and learning.

Research Objectives

As a consequence of previous considerations, we assume that in the PCL, teachers' collective reflection and design, which is highly situated, require the mobilization of contextual knowledge elements. These are necessary for the design of new TEL scenarios that serve as
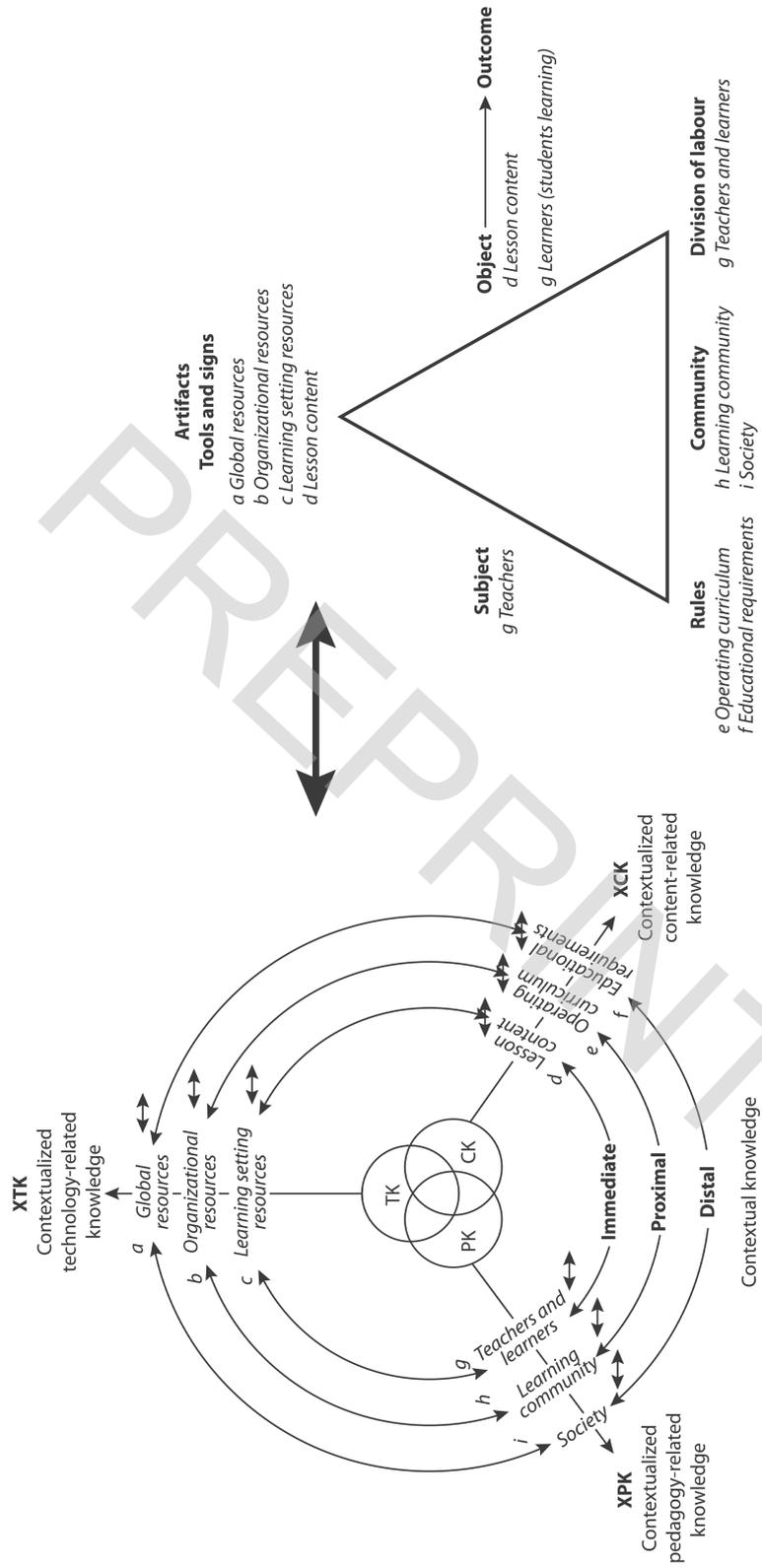
FIGURE 4.3

Transposition of the XTPACK elements (Brianza et al., 2022) into the activity theory model (Engeström, 2015; Engeström and Sannino, 2010).

instruments to transform teaching and learning. This study aims to identify the mobilization of contextual knowledge (XK) elements in teachers' discourse during the PCL.

The primary research question is, "How does the PCL support the mobilization of teachers' contextual knowledge?". Two sub-questions guide the data analysis:

RQ1. What specific XK dimensions and levels are manifested within the teacher team's discussions?

RQ2. How is contextual knowledge enacted in the cycle of expansive learning?

METHODOLOGY

This section outlines the methodology adopted to conduct an empirical analysis of teachers' contextual knowledge (XK) during the PCL.

Methodological Approach: A Qualitative Case Study

To investigate teachers' development of XK in the PCL, we chose a qualitative case study (Merriam, 2009; Stake, 2005; Yin, 2009) which consists of an in-depth examination of a specific phenomenon as it has unfolded in a specific situation (Albarello, 2022). Below, we detail the three components that define the case: the setting and participants, XK elements for data collection, and selected PCL sessions.

Settings and Participants

The study takes place in a French international school in Switzerland, which adheres to the curricula of the French Ministry of Education. The school serves approximately 1150 students in grades 1–12 and employs 90 teachers.

The current case study concerns four participants. They are all lower and upper secondary teachers of French. When the PCL started in spring 2023, each of them had been a teacher for over 20 years (m = 29; sd = 3.5). Three of them had been at the school for nine to sixteen years. One of them had less than a year of experience there (m = 9.42; sd = 6.48), having joined at the start of the academic school year. In spring 2023, the first three had been using digital technologies in their teaching practices for over four years, while the newly hired teacher was only beginning to integrate digital technologies into the classroom.

During the preparation phase of the PCL, teachers collectively expressed their intentions to address didactic and pedagogical issues related to teaching patrimonial literature. To accomplish this, they intended to take full advantage of the digital technologies at their disposal. This permitted the researcher-interventionist to delineate the activity system that would be the object of the transformational process—teaching French literature—and to design a specific formative intervention—the PCL—where co-design of TEL scenarios plays an important role.

Data Collection and Stepwise Procedures of Analysis

The raw data for this study consist of video recordings of the first day of the PCL. The recorded material has a total length of 434 minutes and was manually transcribed verbatim. We first identified three sequences of analysis based on the PCL methodological phases (described in the next section). Then, within each of the three sequences of analysis, topical episodes

were identified according to their substantive contents. We took speaking turns as the unit of analysis, and within each episode, all the speaking turns were analyzed. In total, we analyzed 31 episodes and 1466 speaking turns. Deductive, inductive, and abductive approaches to coding were applied in a combinatorial and recursive process (Moscoso, 2019).

Coding Scheme Development

The data was processed in four stages. In the first step, we have compiled an a priori list of six categories based on the ConteXTPACK framework from Brianza et al. (2022), which consists of three dimensions (social, content, and resources) and three levels (immediate, proximal, and distal) (Figure 4.4). It resulted in a coding scheme with six categories (Table 4.1). In the second step, once we had identified excerpts with contextual knowledge elements in both dimensions and levels, we grouped the XK elements according to the themes observable in each excerpt. This resulted in a first-rank sub-categorization in each of the three dimensions (Table 4.2). In the third step, we found second-rank subcategories, especially when teachers used enough detailed and extensive contextual knowledge. In some first-rank subcategories, we did not find enough elements to define new
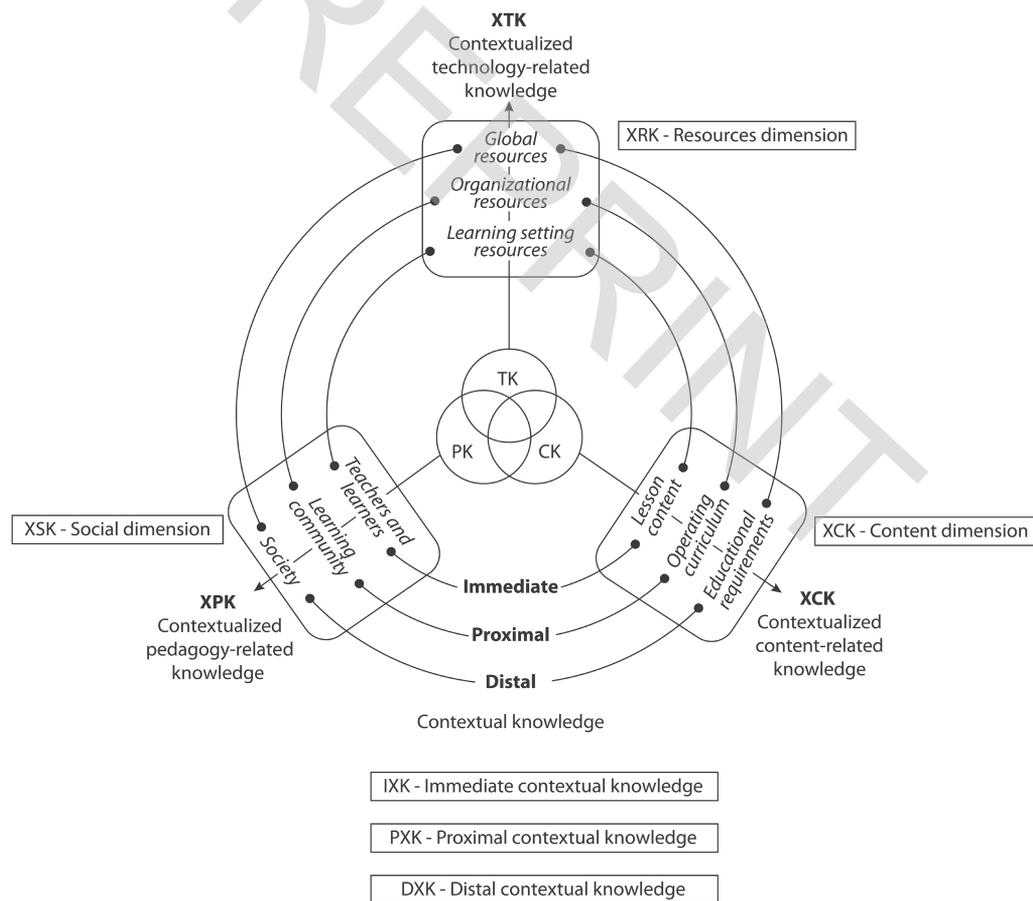
FIGURE 4.4
Identification of six categories based on the ConteXTPACK, adapted from Brianza et al. (2022).

TABLE 4.1
The Six-Category Coding Scheme

Category	Code	Descriptive elements of contextual knowledge identified by Brianza et al. (2022)
Immediate level	IXK	"microlevel"; "setting of the classroom"; "learning environment" (p. 727); "lesson content; teachers and learners; learning setting resources" (p.730)
Proximal level	PXK	"mesolevel, defined as the school or education institution, as well as occasionally including the local community and district" (p.728) / "operating curriculum; learning community; organizational resources" (p.730)
Distal level	DXK	"macrolevel [...], associated with either the national or the global setting, [...] both these settings characterize the macrolevel as an external and overarching system, which influences an individual and local environment but are, generally, beyond an individual's own realm of influence" (p.728) / "educational requirements; society; global resources" (p.730)
Social dimension	XSK	"peer teachers, parents, and administrators"; "collective social aspects, such as cultures, norms, and policies" (p.729) / "teachers and learners, learning community, society" (p.730)
Content dimension	XCK	"lesson content; operating curriculum; educational requirements" (p.730) / "lesson, instructional goal" (p.731)
Resources dimension	XRK	"includes both the relevant tangible and intangible elements"; "physical infrastructure"; "settings" (p.729) / "learning setting resources; organizational resources; global resources" (p.730) / "technological infrastructure" (p.731)

second-rank subcategories. This is true for the first-rank subcategory "school curriculum" and the resources dimension category as a whole. Table 4.3 presents the three-level coding scheme for analyzing the three dimensions. For verification purposes, we carried out a final re-reading of all the selected excerpts, applying the six-category (Table 4.1) and the three-level (Table 4.3) coding schemes.

The Case Under Study Within the Whole Pedagogical Change Laboratory

In this section, we first describe the design of the PCL as a whole, then specify which part of the PCL is the subject of the present case study.

TABLE 4.2
First-Rank Subcategories Identified in Each Dimension

| Category	First-rank subcategories
XSK - Social dimension	XSK-S. Students XSK-T. Teachers XSK-P. Parents XSK-M. Management
XCK - Content dimension	XCK-EP. Educational programs XCK-LT. Learning tasks XCK-SC. School curriculum
XRK - Resources dimension	XRK-DE. School digital ecosystem XRK-DT. Digital technologies (not specifically identified as teaching or learning materials) XRK-TLM. Teaching and learning materials such as books, digital textbooks, and apps

TABLE 4.3
The Three-Level Coding Scheme for the Analysis of the Three Dimensions

Category	First-rank subcategories	Second-rank subcategories
XSK - Social dimension	XSK-S. Students	XSK-S$_1$. Students' knowledge
		XSK-S$_2$. Students' relationship to learning
		XSK-S$_3$. Students' learning difficulties
		XSK-S$_4$. Students' digital practices
		XSK-S$_5$. Students' cultural and linguistic background
		XSK-S$_6$. Students' social interactions
		XSK-S$_7$. Students' workload
		XSK-S$_8$. Students' preferences and pleasure
	XSK-T. Teachers	XSK-T. Collective organization (according to timetables)
	XSK-P. Parents	XSK-P$_1$. Parental expectations and representations
		XSK-P$_2$. Parental homework practices
		XSK-P$_3$. Parental involvement
	XSK-M. Management	XSK-M. Management expectations
XCK - Content dimension	XCK-EP. Educational programs	XCK-EP$_1$. National curricula and their evolution in line with reforms
		XCK-EP$_2$. Institutional didactic guidelines
		XCK-EP$_3$. Assessment standards and their evolution in line with reforms
	XCK-LT. Learning tasks	XCK-LT$_1$. Reading comprehension and literary interpretation
		XCK-LT$_2$. LT. Reading books
	XCK-SC. School curriculum	
XRK - Resources dimension	XRK-DE. School digital ecosystem	
	XRK-DT. Digital technologies (not specifically identified as teaching or learning materials)	
	XRK-TLM. Teaching and learning materials such as books, digital textbooks, and apps)	

Methodological Design of the Pedagogical Change Laboratory

Like the Change Laboratory, the PCL is designed "so that the participants are faced with tasks that call for expansive learning actions" (Engeström et al., 2014, p. 123). These are planned by the researcher-interventionist according to specific methodological steps (Figure 4.5).

The sequence of learning actions follows a process of expansive visibilization, which is "an integral aspect of expansive learning" (Engeström, 2018, p. 199). There are four visibilization phases, and during each phase, the researcher's goal is to prompt specific, expansive learning actions. These actions aim to actively involve teachers in the cycle of expansive learning, as shown in Figure 4.6.

As a setting for expansive visibilization, the PCL, like the Change Laboratory, uses "mirror material" (Engeström, 2011, p. 613) to reflect problems in work practice and diagrammatic models, particularly the triangular model of human activity (Figure 4.1), to recognize and analyze disturbances at both the action and systemic levels (Engeström, 2018). The diagram below (Figure 4.7) illustrates the four expansive visibilization phases and the expansive learning actions altogether. It distinguishes between the two levels of analysis and redesign, i.e., the level of concrete actions and the activity system level.

Visibilization1 focuses on questioning and problematizing aspects of current practices and recognizing inner conflicts. In visibilization2, teachers draft and model past, present, and future forms of their activity system. During visibilization3, they generate new ideas
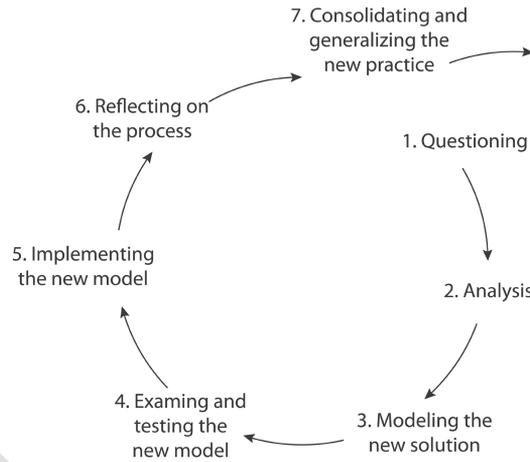
FIGURE 4.5
Sequence of learning actions in an expansive learning cycle.

for further development, co-design new concrete actions, and examine their new solution. Finally, visibilization4 addresses the implementation problems.

The Scope of the Case Study Within the PCL

This study focuses on one part of the PCL, namely the first day, as shown in Figure 4.8. It therefore covers three phases of the PCL, namely visibilization1, visibilization2, and the start of visibilization3.

VISIBILIZATION 1 *Level of inquiry: actions*	**Questioning** and problematizing aspects of current practices Recognizing and **analyzing** inner conflicts in daily practice
VISIBILIZATION 2 *Level of inquiry: from actions to activity*	**Analyzing, modeling** the activity system Discussing historical changes in the activity system Connecting inner conflicts and tensions to systemic contradictions Drafting a vision of the future form of the activity
VISIBILIZATION 3 *Level of inquiry: from activity to possible actions*	Generating ideas for a new model and new forms of action Selecting the best ideas for further development **Modeling** new concrete actions by co-designing new technology-enhanced learning scenarios **Examining and testing** the new solution Preparing the experimental **implementation** of the new solution
VISIBILIZATION 4 *Level of inquiry: actions*	Following and revising the intended and unintended consequences Solving implementation problems **Reflecting** on and evaluating the process with the aim of **consolidating** the new practices

FIGURE 4.6
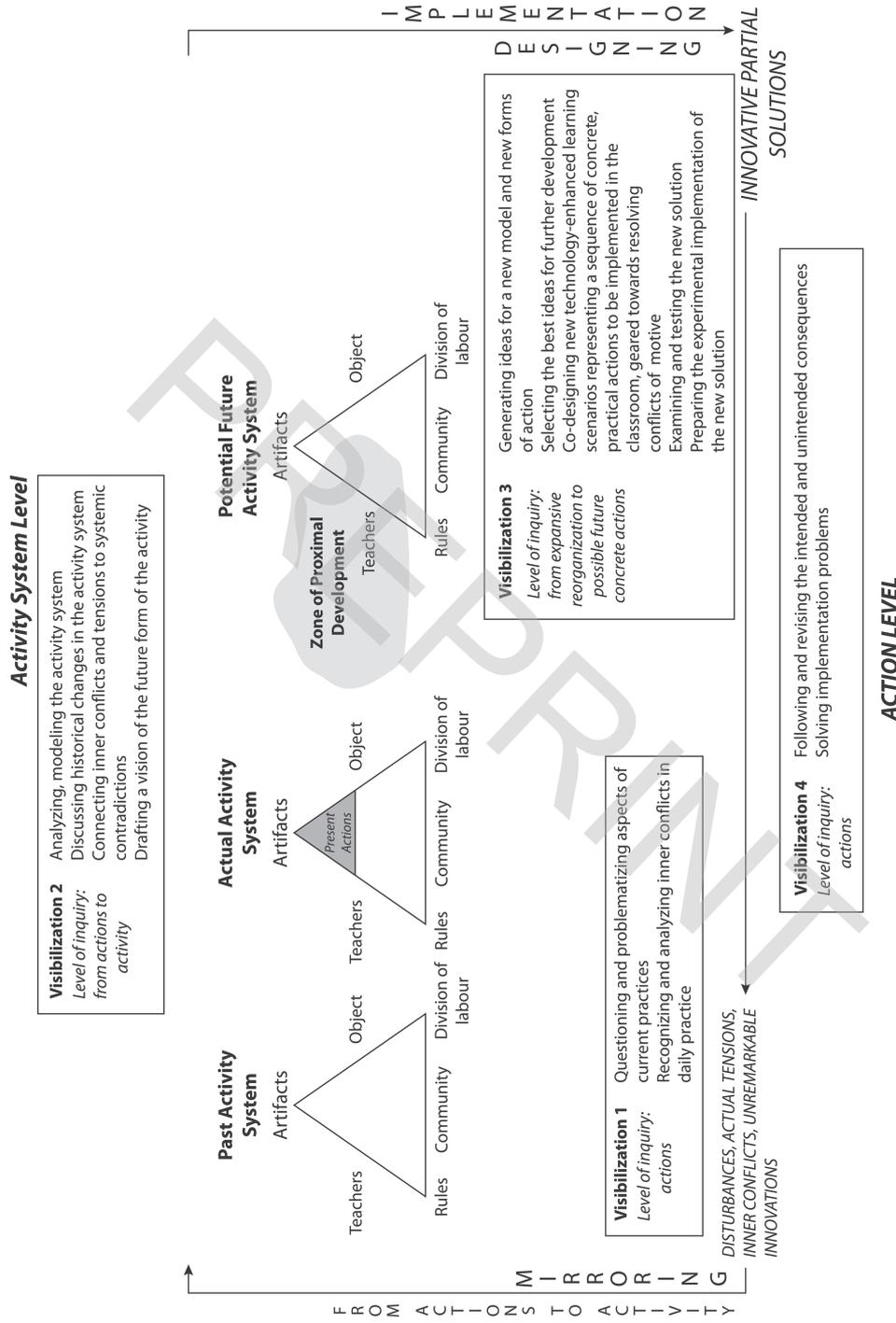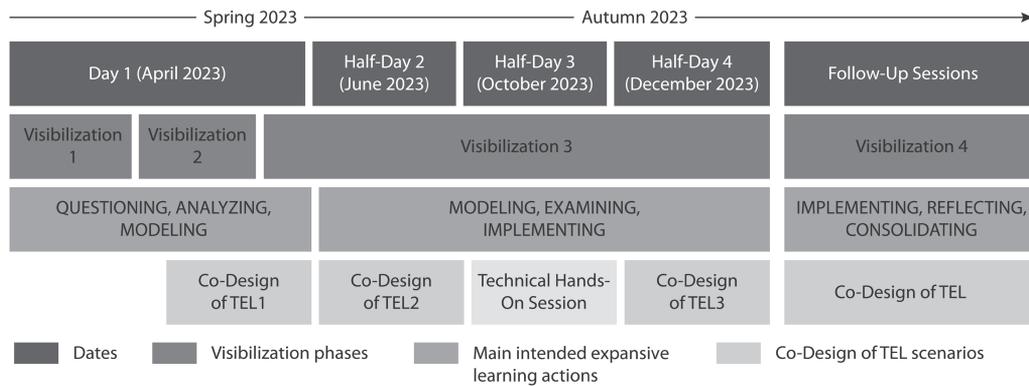**Phases of expansive visibilization and intended expansive learning actions.**

Activity System Level

Past Activity System

Artifacts

Teachers Object Division of labour

Rules Community Division of labour

Actual Activity System

Artifacts

Present Actions

Teachers Rules Object

Division of labour

Community

Potential Future Activity System

Artifacts

Teachers

Object

Rules Community Division of labour

Zone of Proximal Development

Visibilization 2
Level of inquiry: from actions to activity

Analyzing, modeling the activity system
Discussing historical changes in the activity system
Connecting inner conflicts and tensions to systemic contradictions
Drafting a vision of the future form of the activity

Visibilization 1
Level of inquiry: actions

Questioning and problematizing aspects of current practices
Recognizing and analyzing inner conflicts in daily practice

Visibilization 3
Level of inquiry: from expansive reorganization to possible future concrete actions

Generating ideas for a new model and new forms of action
Selecting the best ideas for further development
Co-designing new technology-enhanced learning scenarios representing a sequence of concrete, practical actions to be implemented in the classroom, geared towards resolving conflicts of motive
Examining and testing the new solution
Preparing the experimental implementation of the new solution

Visibilization 4
Level of inquiry: actions

Following and revising the intended and unintended consequences
Solving implementation problems

DISTURBANCES, ACTUAL TENSIONS, INNER CONFLICTS, UNREMARKABLE INNOVATIONS

FROM ACTIONS TO MIRRORING ACTIVITY

IMPLEMENTATION DESIGN ENGINEERING

INNOVATIVE PARTIAL SOLUTIONS

ACTION LEVEL

FIGURE 4.7
Visibilization phases in the pedagogical change laboratory.

FIGURE 4.8
The perimeter of the study within the pedagogical change laboratory.

RESULTS

In this section, we present a comprehensive overview of the results obtained from our study. The presentation follows the structure of the two research questions: exploration of XK dimensions and levels (RQ1) and XK within the cycle of expansive learning (RQ2).

For RQ1, we begin with an overview of each dimension and level (RQ1.1). We then present the XK occurrences according to each dimension for the whole of the PCL without distinguishing between the phases of visibilization (RQ1.2): contextual social knowledge (RQ1.2.1), contextual content knowledge (RQ1.2.2), and contextual resource knowledge (RQ1.2.3).

For RQ2, we begin with a general overview of contextual knowledge occurrences within each expansive visibilization phase (RQ2.1). We then present the contextual knowledge occurrences in each visibilization phase according to the three dimensions (RQ2.2): contextual social knowledge in each visibilization phase (RQ2.2.1), contextual content knowledge in each visibilization phase (RQ2.2.2), and contextual resource knowledge in each visibilization phase (RQ2.2.3).

RQ1.1 Overview of Contextual Knowledge According to the Dimensions and Levels

We observed 69 occurrences of contextual knowledge mobilization during the first day of the PCL. The analysis of the XK occurrences according to the three dimensions and the three levels shows a higher occurrence of the social dimension (social [XSK] n = 38; content [XCK] n = 21; resources [XRK] n = 10) and the immediate level (immediate [IXK] n = 37; proximal [PXK] n = 17; distal [DXK] n = 15).

RQ1.2 Occurrences of Contextual Knowledge According to Each Dimension

A detailed analysis of the contextual occurrences for each dimension is developed below through a three-level hierarchy: categories, first-rank subcategories, and second-rank subcategories.

RQ1.2.1 Contextual Social Knowledge

The social dimension ([XSK] n = 38) is the most represented among the contextual knowledge elements mobilized.
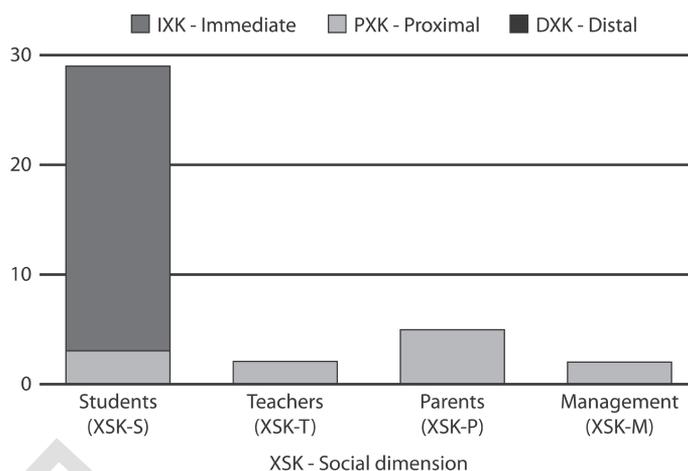
FIGURE 4.9
**Contextual knowledge elements mobilized in the social dimension (XSK): First-rank subcategories
and distribution according to the three levels.**

Distribution of Levels

When teachers mobilize contextual knowledge in the social dimension (XSK), it is mainly at the immediate level (immediate [IXK] n = 26; proximal [PXK] n = 12; distal [DXK] n = 0).

First-Rank Subcategories

The first-rank subcategories of contextual knowledge elements in the social dimension are: students, teachers, parents, and management (Table 4.2). We observe that the first-rank subcategory of the social dimension that is most represented is that of the students (XSK-Students n = 29; XSK-Parents n = 5; XSK-Teachers n = 2; XSK-Management n = 2). This first-rank subcategory (XSK-Students) is mostly situated at the immediate level (immediate [IXK] n = 26; proximal [PXK] n = 3; distal [DXK] n = 0). Thus, regarding the social dimension, the teachers are essentially interested in what is happening at the immediate level of their students.

Second-Rank Subcategories

As mentioned above, in the third stage of the analysis, we have been able to define second-rank subcategories within the first-rank subcategories (XSK-Students, XSK-Teachers, XSK-Parents, XSK-Management). The predominance of contextual knowledge about students (XSK-S) is confirmed by the distribution of the number of second-rank subcategories in the social dimension. In fact, we identified eight second-rank sub-categories relating to contextual knowledge about students, one relating to contextual knowledge about teachers, three relating to contextual knowledge about parents, and one relating to contextual knowledge about school management. The figure below (Figure 4.10) displays the distribution of the number of second-rank subcategories with the four colors corresponding to the four first-rank subcategories (XSK-S., XSK-T., XSK-P., and XSK-M.).
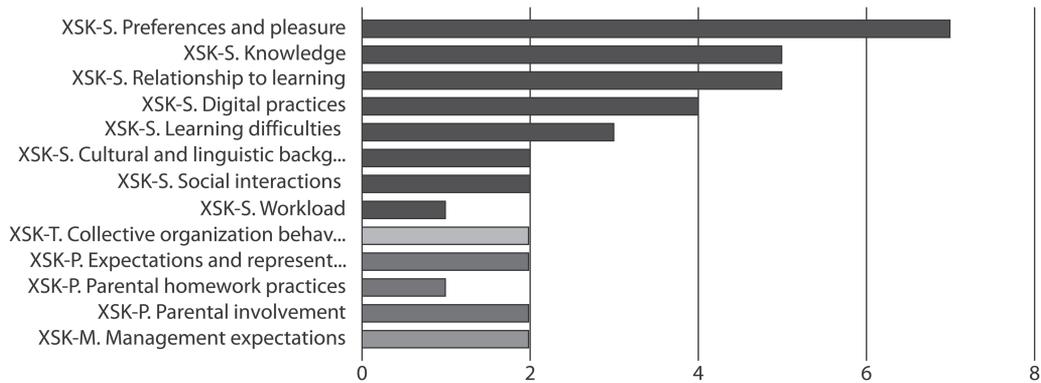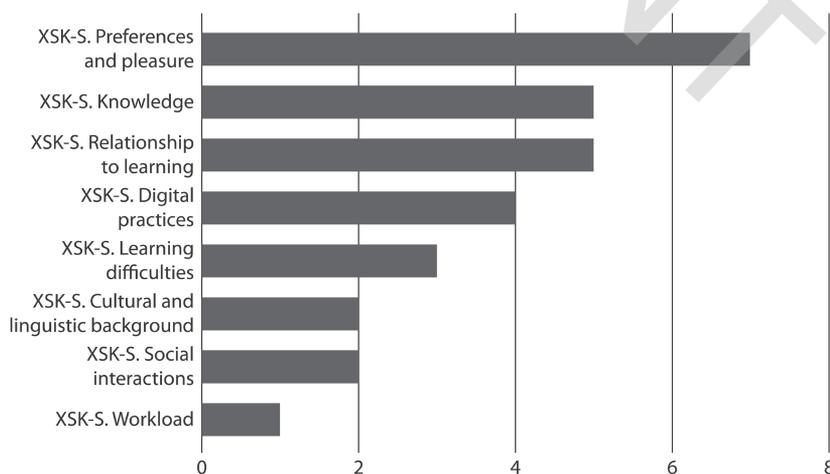
FIGURE 4.10
Second-Rank subcategories in the social dimension.

SECOND-RANK SUBCATEGORIES RELATING TO STUDENTS (XSK-S)

Regarding teachers' contextual knowledge of students specifically (Figure 4.11), the most frequently cited items are related to: students' preferences and pleasure (n = 7), students' knowledge (n = 5), and students' relationship to learning (n = 5). We note that these three contextual knowledge elements are closely linked to the pedagogical and didactic problems that teachers set themselves to address in the PCL through the co-design of new TEL scenarios. Indeed, during visibilization3, right after recognizing the disturbances in their daily practices and analyzing their activity system, and before the first co-design session, the teachers explicitly stated their intention to design a new TEL scenario aimed at changing students' relationship to learning literature by increasing their engagement and pleasure in school reading.

SECOND-RANK SUBCATEGORIES RELATING TO PARENTS (XSK.P)

Regarding contextual knowledge about parents (n = 5), two of the occurrences concern the teacher who had arrived at the school only six months earlier. She described some of the

FIGURE 4.11
Distribution of cited items in second-rank subcategories relating to students.

difficulties she had faced, especially concerning the use of digital tablets. Implicitly, her remarks revealed that these difficulties were specifically caused by her lack of contextual knowledge about parents. Although the school is running a one-to-one project, parents generally expect lessons to be written in the student's notebook. But this teacher, thinking she was doing the right thing, had the pupils write their lessons on their tablets, which irritated some parents.

Second-Rank Subcategories Relating to Peer Teachers (XSK.T)

In teachers' discourse, XK about peer teachers (n = 2) is linked to what motivates the participants in the PCL, namely, increasing students' engagement and enjoyment in learning literature. Indeed, contextual knowledge elements about peer teachers in the school are mentioned when the participants evoke their desire to decompartmentalize the teaching and learning of literature through transdisciplinary activities.

RQ1.2.2 Contextual Content Knowledge

Distribution of Levels

When teachers mobilize contextual knowledge in the content dimension (XCK), it is mainly at the distal level (immediate [IXK] n = 6; proximal [PXK] n = 1; distal [DXK] n = 14). The results for the subcategories, which we present below, shed light on the reasons why contextual knowledge in the content dimension is mainly located at the distal level.

First-Rank Subcategories

The first-rank subcategories of contextual knowledge elements in the content dimension are: educational programs (n = 14), learning tasks (n = 6), and school curriculum (n = 1). The findings for the content dimension demonstrate that the majority of the contextual knowledge elements that the teachers mobilized are associated with the first-rank subcategory "educational programs", which is located at the distal level (Figure 4.12). These results
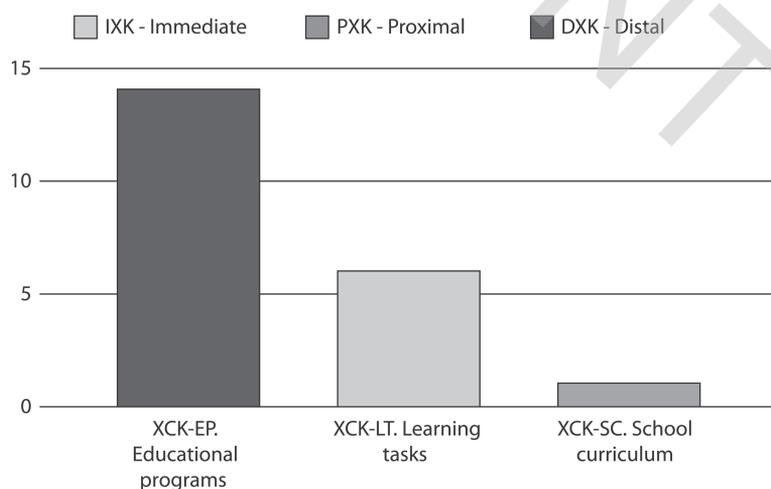
FIGURE 4.12
Contextual knowledge elements mobilized in the content dimension (XCK): First-Rank subcategories and distribution according to the three levels.

are consistent with the situation analyzed by the teachers during the PCL. Indeed, from the outset, they noted a major and growing tension between the national curriculum and students' pleasure in school reading. This corresponds to a systemic contradiction between two components in their activity system, namely the rules and the object (see Figure 4.1). As a result, the educational programs play an important role in their concerns, and this is also why teachers, in visibilization3, decided to co-design new TEL scenarios aimed at increasing students' pleasure in school reading while respecting the imposed curriculum.

Second-Rank Subcategories

We found second-rank subcategories in relation to educational programs and learning tasks (Figure 4.13). The two most represented second-rank subcategories in our results are consistent with teachers' decisions at the end of visibilization2, as they determined that their new TEL scenarios should support the comprehension and interpretation of literary texts (n = 5) while reconciling the pleasure in school reading with the requirements of the national curricula (n = 10).

RQ1.2.3 Contextual Resources Knowledge

During the first day of the PCL, contextual knowledge in the resources dimension is less mobilized than in the other two dimensions. As indicated in the methodology section, we only identified first-rank subcategories in the resources dimension.

Distribution of Levels

When teachers mobilize contextual knowledge in the resources dimension (XRK), it is mainly at the immediate and proximal levels (immediate [IXK] n = 5; proximal [PXK] n = 4; distal [DXK] n = 1).
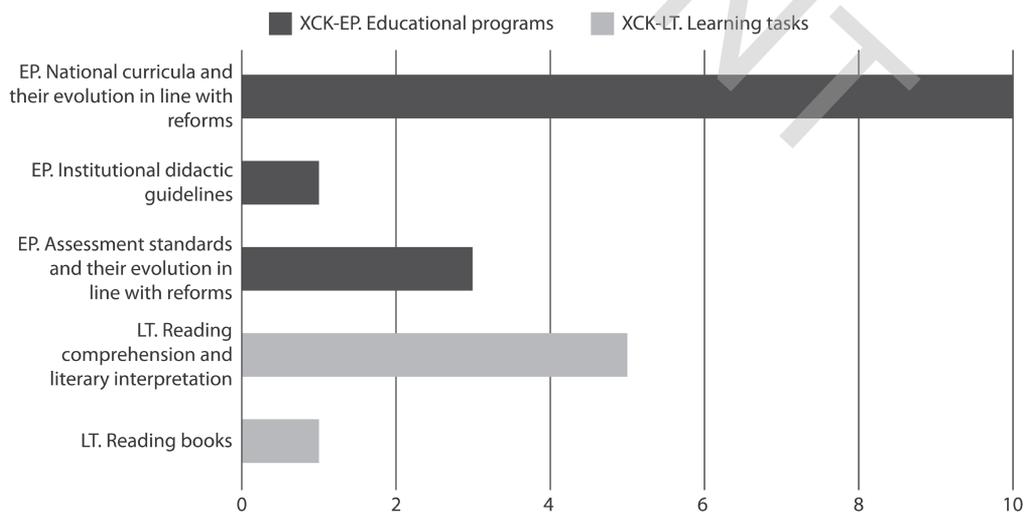
FIGURE 4.13
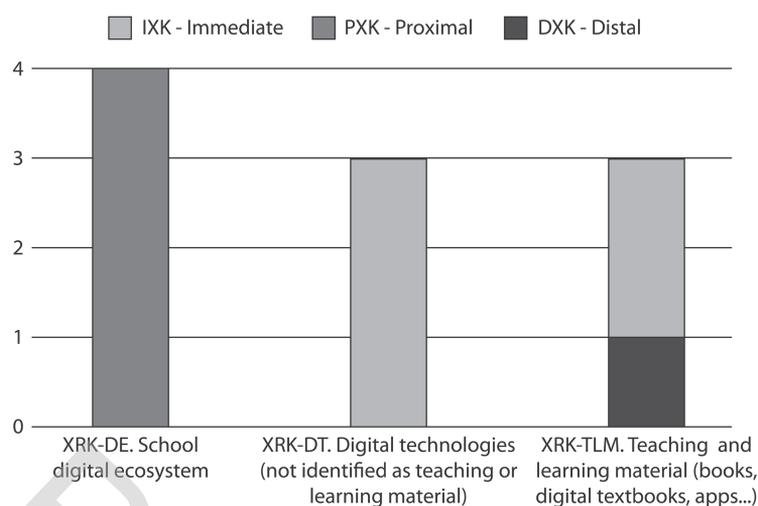**Second-Rank subcategories in the content dimension.**

FIGURE 4.14
Contextual knowledge elements mobilized in the resources dimension (XRK): First-Rank subcategories and distribution according to the three levels.

First-Rank Subcategories

The first-rank subcategories we have found in the resources dimension (Figure 4.14) are as follows: school digital ecosystem (n = 4), digital technologies (n = 3), teaching and learning material (n = 3). An examination of the excerpts containing these first-rank subcategories reveals two notable observations relating to the school digital ecosystem and digital technologies, which we develop below.

Contextual Knowledge About the School Digital Ecosystem (XRK-DE)

We found four occurrences of contextual knowledge elements relating to the school digital ecosystem ([XRK-DE] n = 4). In three cases out of four, this concerned the teacher, who had been at the school for less than a year. Her comments reveal a lack of contextual knowledge about the school's digital ecosystem, which has resulted in disturbances in her daily practice.

Contextual Knowledge About Digital Technologies (XRK-DT)

An analysis of the teachers' discourse reveals that the contextual knowledge elements identified in the "digital technologies" category are all about ChatGPT. Teachers always relate these elements to the social dimension (specifically to the students) and to the content dimension (specifically to learning tasks and educational programs). This means that teachers consider ChatGPT as an important contextual element, particularly with regard to their students' engagement in the learning process and the way students use Generative AI to complete their assigned reading tasks with little effort. Teachers feel that students' use of ChatGPT does not encourage them to engage in authentic reading of literary texts and notice that it does not seem to have a negative impact on their success in exams, since these consist more of reproducing knowledge than of demonstrating an authentic and personal understanding of literary works.
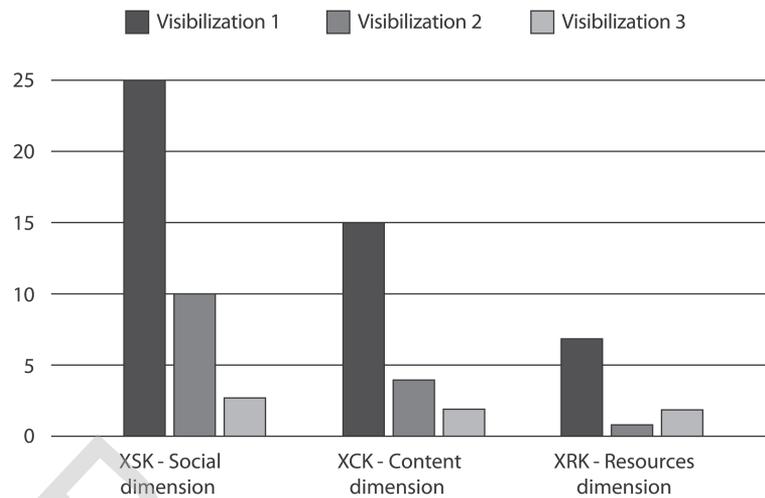
FIGURE 4.15
Contextual knowledge occurrences in each visibilization phase for each dimension.

RQ2.1 Overview of Contextual Knowledge Within the Cycle of Expansive Learning

As mentioned above (Figures 4.5–4.7), expansive learning actions are articulated through four visibilization phases. The first day of the PCL, which concerns our study, includes the first two phases and the start of the third one (Figure 4.9). In this section, we present the mobilization of contextual knowledge according to the three visibilization phases.

XK is mobilized during the three visibilization phases: visibilization1 (n = 47); visibilization2 (n = 15); and visibilization3 (n = 7). It is at the highest level in visibilization1 (n = 47), where the main expansive learning actions consist of questioning the current situation and analyzing the tensions experienced in daily practice. Focusing primarily on systemic analysis, visibilization2 induces a higher level of conceptual thought and appears to require less mobilization of contextual knowledge elements (n = 15). Visibilization3, which mainly involves modeling novel solutions by co-designing new TEL scenarios, is the phase in which we find the least traces of contextual knowledge in conversations (n = 7). The results for each dimension confirm the previously observed trend, namely a decrease of XK traces between visibilization1 and visibilization3 (Figure 4.15).

RQ.2.2 Contextual Knowledge Dimensions in Relation to Expansive Visibilization Phases

RQ2.2.1 Contextual Social Knowledge in Each Visibilization Phase

As regarding occurrences of contextual social knowledge, we first present the results in the first-rank subcategories (Figure 4.16), then the results in the second-rank subcategories about students (Figure 4.17).

First-Rank Subcategories

We detail below the first-rank subcategories concerning peer teachers and students.
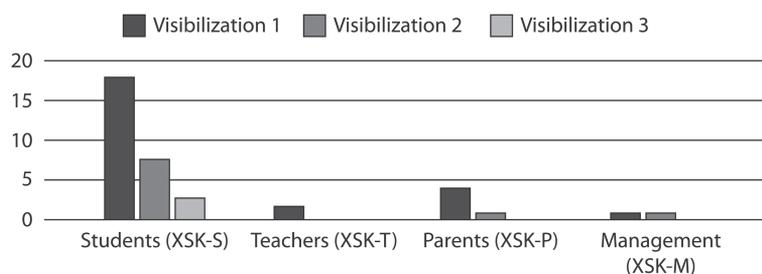
FIGURE 4.16
First-Rank subcategories in the social dimension for each visibilization phase.

Contextual Knowledge About Peer Teachers in Each Visibilization Phase

Contextual knowledge about peer teachers only appears in the first phase (visibilization1, n = 2; visibilization2, n = 0; visibilization3, n = 0). As previously mentioned, participants discussed the value of collaborating with teachers of other subjects to add meaning to learning literature by opening it up to other perspectives. However, noting the numerous organizational obstacles they have already faced, they focused on alternative ways of solving their didactic and pedagogical problems. This avenue for resolving their problems has been abandoned in the visibilization1, the participants will no longer use this contextual element in the following phases.

Contextual Knowledge About Students in Each Visibilization Phase

As shown in Figure 4.16, contextual knowledge about students (XSK-S) is observed during all the visibilization phases (visibilization1, n = 18; visibilization2, n = 8; visibilization3, n = 3). Importantly, in the social dimension, contextual knowledge about students is the only first-rank subcategory observable during visibilization3. To better understand how XK about students unfolds during the three visibilization phases, we present below the results for second-rank subcategories about students.
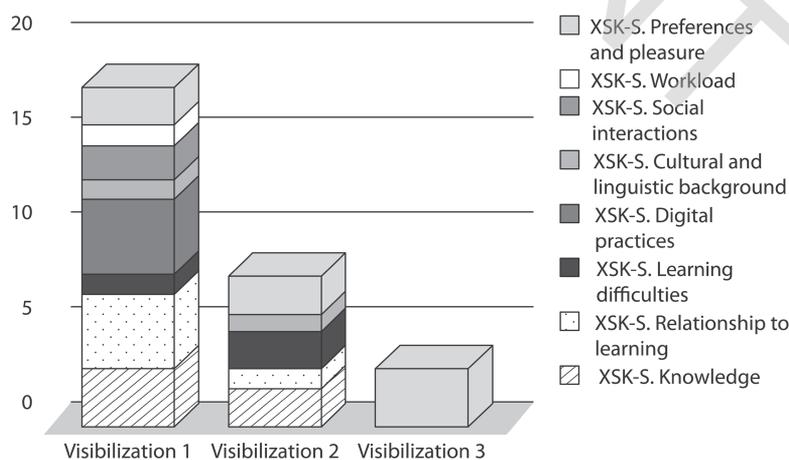
FIGURE 4.17
Second-Rank subcategories concerning students for each visibilization phase.
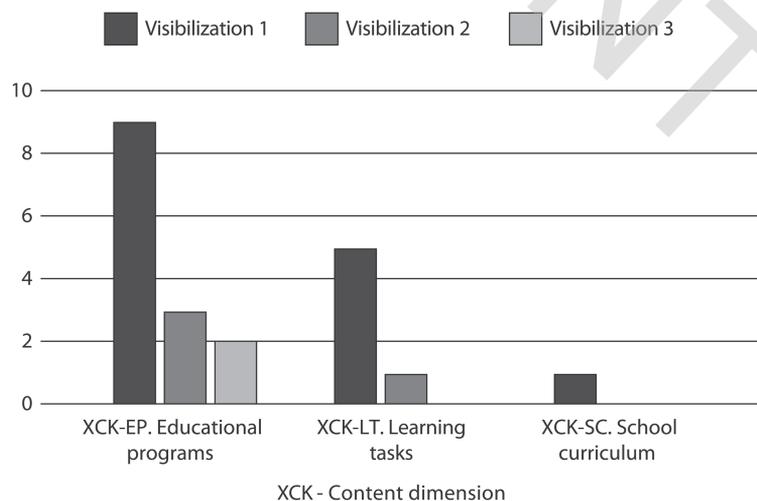
Second-Rank Subcategories About Students

As shown in Figure 4.17, of the second-rank subcategories relating to students, only the "students' preferences and pleasure" category is observed during the three visibilization phases (visibilization1, n = 2; visibilization2, n = 2; visibilization3, n = 3). Furthermore, it is worth noting that this is the only category observed during visibilization3.

*RQ2.2.2 Contextual Content Knowledge in Each Visibilization Phase*

As shown in Figure 4.18, the "educational programs" category is observable in all phases (visibilization1, n = 9; visibilization2, n = 3; visibilization3, n = 2). The "learning tasks" category appears in visibilization1 and visibilization2 (visibilization1, n = 5; visibilization2, n = 1; visibilization3, n = 0). Below, we detail the results for these two categories. We first present the results concerning the "learning tasks" category. We then present the results concerning the "educational programs" category, with a focus on two second-rank subcategories, namely the "national curricula" and "assessment standards", which are the most frequently cited elements (Figure 4.19).

Contextual Knowledge About Learning Tasks in Each Visibilization Phase

Contextual knowledge about learning tasks appears in visibilization1 and visibilization2, which focus primarily on questioning current practices and analyzing the activity system. This contextual knowledge element does not appear anymore in visibilization3. Teachers, however, do refer to learning tasks throughout the design process during visibilization3. In this phase, they come up with new learning tasks, and their conversations primarily show the enactment of PCK, TPK, and TPACK rather than the mobilization of contextual knowledge. To illustrate our point, we cite below an excerpt from visibilization3 when teachers co-designed their first new TEL scenario. We note that the conversation focuses on learning tasks and digital technologies, articulating

FIGURE 4.18
First-Rank subcategories in the content dimension for each visibilization phase.
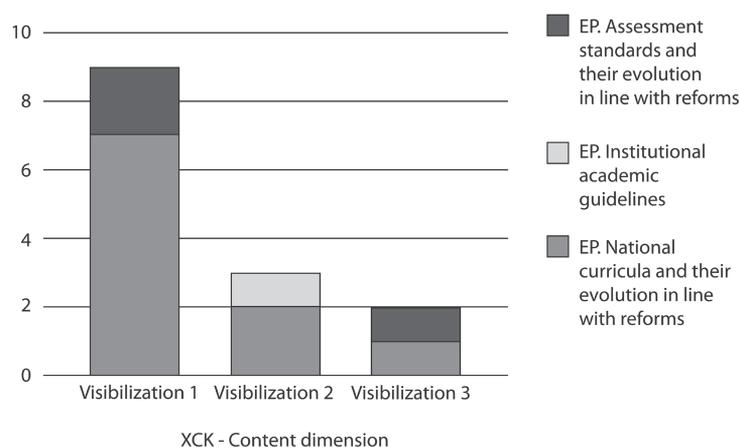
FIGURE 4.19
Second-Rank subcategories concerning educational programs.

pedagogical, technological, and content-related issues, demonstrating their TPACK knowledge.

> P1. We could suggest that they create multimodal productions from a text, for example uh… an advertising poster on a literary work, the creation of a magazine cover on the events of a novel, etc. I don't know… What else can they do?

> P2. Fake telephone conversations or fake video conferences… from fictional characters in a novel, from an author…

> P3. An adaptation of literary extracts into comics or into a short movie?

> […]

> P2. And if they use applications on the tablet to carry out these multimodal productions, do we then tell them to make and print QR codes to put them in the paper reading log?

In contrast, as shown in the excerpt below, the references to learning tasks in visibilization1 are of a contextual nature. Indeed, the topic at hand was about literary interpretation and reading comprehension. Both of these learning tasks were mentioned when teachers reflected on aspects of students' knowledge, relationship to learning, and learning difficulties. During visibilization1, teachers mobilized XK elements about learning tasks to understand the pedagogical and didactic difficulties they declared they regularly faced in their teaching practice.

> P2. I think that misinterpretations and erroneous literary interpretations that students make should always be taken with great kindness and caution because often they have already done something very well. The problem is that they don't have literary codes. In fact, I think that, with goodwill, they are trying to imitate us. I think that the student who makes fanciful interpretations imitates his teacher […] and then it's difficult to make them understand why it's fanciful.

> P1. Yes, I think they don't really read the text; it's the knowledge that they seek to apply rather than letting the text speak.

Contextual Knowledge About Educational Programs in Each Visibilization Phase

We note that, unlike the other first-rank subcategories relating to the content dimension, contextual knowledge about educational programs is mobilized during the three visibilization

phases. This is consistent with teachers' developmental trajectory throughout the visibiliza-
tion phases during the first day of PCL. Indeed, as previously stated, the primary issue that
teachers have identified and decided to address (visibilization1–visibilization2) through new
TEL scenarios (visibilization3) concerns the national curriculum and assessment standards,
which over time have steadily reduced the time that they can devote to the pleasure of reading.
Figure 4.19 displays the second-rank subcategories of educational programs. Contextual
knowledge relating to the national curricula and their evolution over time is observable in all
the visibilization phases (visibilization1, n = 7; visibilization2, n = 2; visibilization3, n = 1),
and contextual knowledge about assessment standards can be observed in visibilization1
(n = 2) and visibilization3 (n = 1).

RQ2.2.3 Contextual Resources Knowledge in Each Visibilization Phase

Regarding contextual resources knowledge, we present results in the first-rank categories. As
indicated above, no second-rank subcategories have been identified in this dimension dur-
ing the first day of the PCL. We note that contextual knowledge elements related to resources
are mobilized during all the visibilization phases (Figure 4.20). In particular, we present the
results concerning digital technologies and the school's digital ecosystem.

Contextual Knowledge About Digital Technologies In each Visibilization Phase

Contextual knowledge about digital technologies appears only in visibilization1 (visibi-
lization1, n = 3; visibilization2, n = 0; visibilization3, n = 0). As previously mentioned,
teachers referred to students' use of Chat GPT to carry out reading tasks with little effort.
In this phase, contextual knowledge about digital technologies helped question current
practices and analyze actual disturbances in teaching and learning literature, which cor-
respond to the first two expansive learning actions in the cycle of expansive learning.
In addition, we observe that teachers did refer to digital technologies in visibilization3,
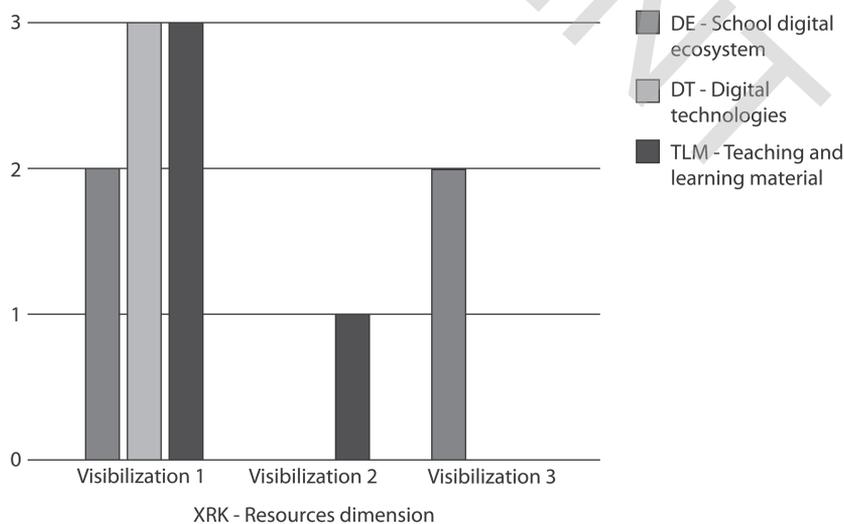
FIGURE 4.20
Contextual resource knowledge occurrences in each visibilization phase.

but the analysis shows that it is no longer contextual knowledge. During visibilization3, digital technologies are considered by teachers as components of a new TEL scenario to model future practices, and this relates to other types of knowledge such as TCK, TPK, and TPACK.

Contextual Knowledge About the School Digital Ecosystem in Each Visibilization Phase

Contextual knowledge relating to the school digital ecosystem is mobilized in visibilization1 and visibilization3 (visibilization1 n = 2; visibilization2 n = 0; visibilization3 n = 2). These findings prompt us to make two observations about the relation between this contextual knowledge category and expansive learning actions in visibilization1 and visibilization3.

Visibilization1

As previously highlighted, XK about the school digital ecosystem was mobilized in visibilization1 by the teacher, who has only been teaching at this school for a few months. During this phase, none of the other three teachers made any mention of the school's digital ecosystem. It is worth noting that the newly hired teacher expressed the need to further develop her contextual knowledge about the school's digital ecosystem while questioning current practices and analyzing disruptions in daily activities. It was through these two expansive learning actions that this teacher was able to recognize the need to develop her XK.

Visibilization3

In visibilization3, teachers mobilized their XK relating to the school digital ecosystem as they discussed the technological support they would use to implement a digital reading log. They began by evoking the storage space that students are typically assigned. Then they discussed the technologies available to students, as well as the compatibility of certain technologies with the students' devices. This prompted them to abandon the idea of using a specific one because there is no tablet application for it. When we read the speaking turns, we noticed that in visibilization3, i.e., the co-design session no. 1, the distinction between XK related to the school digital ecosystem and other types of knowledge in the TPACK framework appears to blur at times. To illustrate our point, we cite the following excerpt.

> P2. We could also use Genially.
>
> P1. Oh no, not Genially! Students hate Genially because it's not practical on the tablet. It's great on a computer, but with a tablet, it's not practical at all.
>
> P2. Yes, you're right, and if we choose Genially, we will have to take the laptop trolley. That is not suitable for a digital reading notebook that we want to use often.

Indeed, it is difficult to determine what type of knowledge the mentions of the school digital ecosystem refer to in this excerpt. We hardly discriminate between XK about the school digital ecosystem and TPACK since the discussion focuses on the technological and pedagogical conditions for implementing a digital reading log to teach and learn literature. Based on the XTPACK framework (Brianza et al., 2022), we identify this type of knowledge as contextualized-TPK-related knowledge.

DISCUSSION

This chapter aims to study the development of in-service teachers' contextual knowledge (Brianza et al., 2022; Mishra, 2019) during the PCL, a TPACK professional development intervention in the workplace, situated within CHAT.

In this section, we first return to each research question. We then highlight key findings related to implications and recommendations before presenting limitations and future directions.

Distribution of XK Dimensions and Levels in Teachers' Conversations

The findings (RQ 1.1–1.2) reveal that teachers' conversations during the first day of the PCL encompassed all dimensions (social, content, and resources) and levels (immediate, proximal, and distal) of contextual knowledge (XK), as defined in the XTPACK framework (Brianza et al., 2022). Notably, the majority of the contextual knowledge elements mobilized by teachers on the first day of the PCL concern the social dimension and the immediate level. These findings are consistent with those of Brianza et al. (2022), who found a predominance of both microlevel and social-related elements.

As for the social dimension (RQ1.2.1), teachers predominantly relied on contextual knowledge about their students. This also aligns with the findings of Brianza et al. (2022), which indicate that teachers primarily focus on the microlevel of the learning activity. Among the eight second-rank subcategories concerning students, the highest rates of contextual elements concern first students' preferences and pleasure, followed by students' knowledge and their relationship to learning. These results reflect the main objective of the teachers in the PCL: to transform their practices in order to increase their students' engagement and enjoyment in learning literature.

Regarding the content dimension (RQ1.2.2), the majority of the contextual knowledge elements have to do with educational programs at the distal level, including both national curriculum and standard assessments. We first note that these findings are consistent with previous studies that have shown a high pressure on curricular constraints in secondary education (Hill & Uribe-Florez, 2020) and highlighted the impact of external priorities, such as national exams or department policies, on teachers' design decisions (Boschman et al., 2015). Importantly, during the PCL, the teachers expressed the tension they felt most strongly between the need to comply with the curriculum, including exam preparation, and the desire to transmit the pleasure of reading literature to their students. On the diagram representing their activity system (see Figure 4.1), they drew the main contradiction they wished to reduce between the object of their activity, i.e., teaching literature, and the rules governing their activity, i.e., the imposed curriculum and standard assessments. Breaking out of this conflicting situation (educational programs vs. students' pleasure) is the main objective guiding the co-design of a new TEL scenario. During the first day of the PCL, XK about educational programs (macro-level) is most often linked to XK about students (micro-level), especially about their engagement in learning literature, their relationship to learning, and their pleasure in reading. These results are in line with the observations made by Brianza et al. (2022), since they seem to confirm the tendency for the macro-level to be associated with the micro- or meso-level. The way teachers mobilize content-related XK seems to demonstrate that "for contextual elements to be regarded by teachers as meaningful for practice, they must either directly fall within their realm of influence or at least be perceived as related to these realms" (Brianza et al., 2022, p. 728).

As regards the resources dimension (RQ1.2.3), immediate and proximal levels are prominent. This reflects the importance of taking resources into account at the classroom and school level. Through an examination of discussions in which teachers mobilized XK in relation to the school digital ecosystem, we observed that a lack of this type of XK is a barrier to effective integration of technology. In the "digital technologies" category, XK elements are most often associated with both social and content dimensions, in particular with students and learning tasks. Notably, each time teachers referred to ChatGPT as a contextual element to consider [resources dimension - distal level], it was in relation to their students, especially to their relationship to learning [social dimension - immediate level], and the way they used AI to carry out prescribed reading tasks with reduced efforts [content dimension - immediate level]. These results highlight the complex relationships between various factors that teachers manage in their daily practices (Kelly, 2008; Rosenberg & Koehler, 2015). The interconnection of these factors is evident in the discussions among teachers during the PCL, revealing intricate connections between various levels and dimensions of XK. Moreover, the mentions of ChatGPT as an XK element in teachers' conversations echo Rosenberg and Koehler (2015), who emphasize that macro-level elements, while outside the scope of the school and the classroom, can have a significant impact on teaching and learning.

Enactment of Teachers' Contextual Knowledge Within the Expansive Visibilization Process

The second research question (RQ2) aims to identify contextual knowledge enactment within the cycle of expansive learning. The findings (RQ 2.1) indicate that teachers mobilized their XK primarily during visibilization1 and visibilization2. The use of XK decreased significantly during visibilization3. To put this reduction of XK into perspective, we will now outline teachers' trajectory within the expansive visibilization phases of the PCL. During visibilization1, the teachers expressed a tension in their daily practice manifested as a conflict of motives (Sannino, 2015) between the desire to transmit the pleasure of literature and the need to prepare their students for exams in compliance with national curriculum requirements. During visibilization2, the teachers recognized in their activity system a contradiction between the object of their activity—teaching literature—and the educational programs (see object and rules components in Figure 4.1). In visibilization3, they set out to find a way to combine the pleasure of school reading with the requirements of the national curricula, and they decided to co-design a new TEL scenario that would help resolve this conflict. To account for the notable decline of XK in visibilization3, we propose the hypothesis that the initial two phases of visibilization enabled teachers to define the problematic situation and determine the direction they wanted to take with a new TEL scenario. As a result, they no longer needed to rely as heavily on XK as they did previously. In addition, as stated in our results, during the co-design session no. 1 in visibilization3, XK appeared to merge with other domains of knowledge described in the TPACK framework, reducing the number of XK elements that can be observed. This does not mean that teachers no longer considered their context when co-designing; rather, it seems that their TPACK was "contextualized by being situated within contextual knowledge" (Brianza et al., 2022, p. 731). These results are consistent with what we have observed in all the data collected to date. Although the primary focus of this study is not on the mobilization of TPACK, it is worth noting that our data demonstrate an increase in TPACK mobilization simultaneously with a decrease in XK mobilization, starting from the co-design session no. 1. Furthermore, by calculating the frequency of

XK elements in each dimension and each expansive visibilization phase (RQ2.2), we were able to identify significant differences, both between and within dimensions.

Regarding the social dimension (RQ2.2.1), we first note that there is a large amount of XK elements in visibilization1 compared with visibilization2, where there is much less. It is worth noting that in visibilization2, teachers were invited to adopt a more conceptual approach to analyzing their activity system, which could explain why their contextual knowledge was less mobilized. Secondly, our results show that XK relating to students is the only one observed across all of the expansive visibilization phases. More precisely, the second-rank subcategory "Students' preferences and pleasure" is the only one that appears in all of the visibilization phases. Additionally, we note that the first XK element mobilized by teachers in the PCL falls under the category "Students' preferences and pleasure", which is also the most prevalent category in visibilization3. These findings are consistent with the main objective that teachers have set for themselves in the PCL: co-design a new TEL scenario aimed at changing their students' relationship to literature, specifically by increasing their pleasure in reading.

In terms of the content dimension (RQ2.2.2), it should be noted that with "students", in particular "students' preferences and pleasure", the categories "educational programs" and "national curriculum" are the only ones to appear in all the visibilization phases. These prominent and persistent XK elements in the PCL correspond to the main contradiction identified by the teachers in their activity system (Figure 4.21). Notably, these XK elements reflect the central conflict of motives that teachers set out to resolve. Resolving this conflicting situation (national curriculum constraints versus students' preferences and pleasure) is the main driver of change (Engeström et al., 2022) in the PCL and also provides direction for the new TEL scenario. This suggests that the PCL methodology, which relies on teachers identifying conflicting motives and systemic contradictions in their
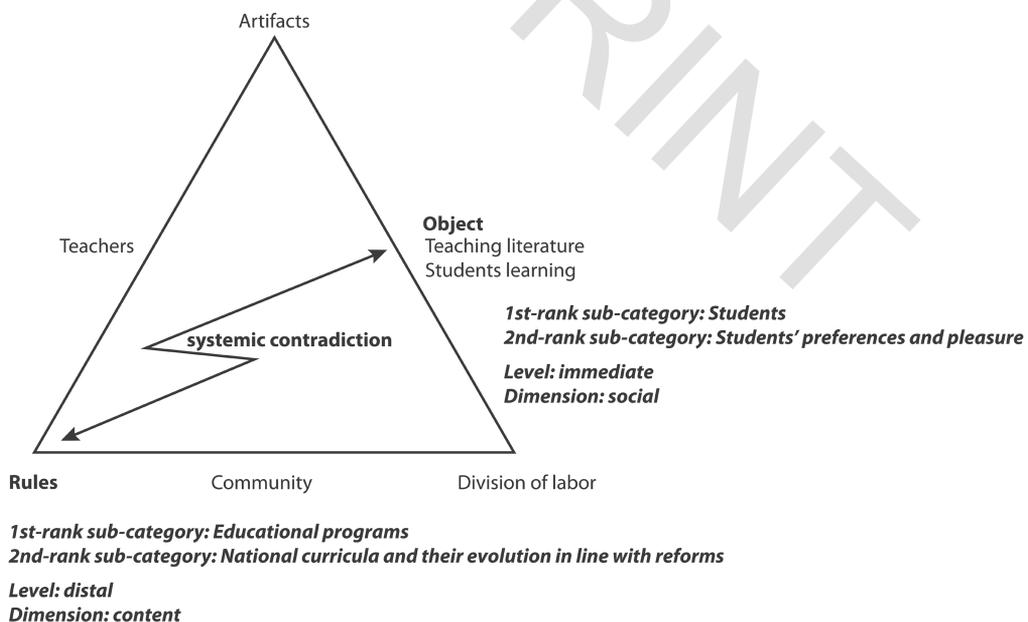

FIGURE 4.21
The prominent and persistent XK elements enacted during the PCL and the main contradiction identified by teachers within their activity system.

activity system, encourages the enactment of XK to co-design a new TEL scenario. Moreover, XK about learning tasks appears in visibilization1 and visibilization2, when teachers analyzed the pedagogical and didactic problems they regularly faced in their daily practice. However, this type of XK is no longer seen in visibilization3. This may appear unexpected, especially when the objective is to design a pedagogical scenario. Our hypothesis is that visibilization3, which includes the co-design sessions, is future-oriented (Duret & Romero, 2022; Sannino & Engeström, 2017). As a result, teachers no longer discussed contextual elements in relation to their current practices, but rather potential future learning tasks, enacting their PCK, TPK, TCK, and TPACK when designing a new TEL scenario. This transition from XK to other TPACK knowledge domains suggests a transformation from standalone contextual knowledge to a more complex integration as teachers engaged in the co-design activity. In other words, while designing, teachers no longer enacted XK in isolation but rather integrated XK within other TPACK domains of knowledge, which Brianza et al. (2022) refer to as "contextualized knowledge", as it is "situated within contextual knowledge" (p. 731).

Concerning the resources dimension (RQ2.2.3), XK about the school digital ecosystem is mobilized in visibilization1 and visibilization3. Notably, during visibilization1, a participant explicitly recognized the need for XK development while questioning practices and analyzing disturbances in daily teaching, which correspond to the first two steps in the cycle of expansive learning. This suggests that these expansive learning actions could help teachers acknowledge the significance of XK when it comes to integrating technology into teaching. In addition, similar to the phenomenon we noticed in the content dimension during the co-design process, we are once again observing a transition from "school digital ecosystem" XK to TPACK as teachers engage in designing their new TEL scenario. Regarding XK about digital technologies, we see that it is first enacted in visibilization1. While questioning their practices and analyzing the disturbances in their daily teaching, teachers made three references to ChatGPT and identified GenAI as a risk to the way students' learning tasks can be completed effortlessly. It is worth mentioning that in visibilization3, which is primarily devoted to modeling, the teachers integrated GenAI as one of the digital tools in a new TEL scenario. They did this during the co-design session no. 3. This means that in visibilization3, ChatGPT was no longer considered only as a tool that the students chose to reduce their efforts in learning literature. Instead, teachers integrated the use of ChatGPT to help their students understand a notoriously difficult 17th-century literary work. The reevaluation of ChatGPT exemplifies the teachers' ability to shift from a tool perceived merely as a means for students to minimize effort (visibilization1) into a tool to support the students' understanding of complex texts (visibilization3). First, this echoes the need to consider GenAI within the contextual knowledge (XK) of TPACK (Mishra et al., 2023). Secondly, this reveals how much GenAI challenges education, requiring teachers to transform teaching and learning, reconsider how the content should be taught, and envision alternative pedagogical approaches (Mishra et al., 2023). It also shows that when teachers are aware of contextual issues, both mindful of constraints and receptive to future possibilities, they can turn problematic pedagogical situations into new forms of teaching and learning (Mishra & Warr, 2021). These findings appear to demonstrate that the successive expansive learning actions in the PCL, namely questioning, analyzing, and modeling by designing new TEL scenarios, can assist teachers in the transformation of teaching|learning activity. Through this example, we see that the enactment of XK related to students, including their digital practices, and XK related to resources, including digital technologies, resulted in a new TEL scenario demonstrating teachers' TPACK.

Implications and Recommendations for Future Research

This study contributes to the theoretical foundation of contextual knowledge (XK) as a knowledge construct within the TPACK framework (Mishra, 2019).

Dynamic Interconnection of Levels and Dimensions Within the Contextual Knowledge Domain

The findings confirm the conceptualization of XK as a three-level (immediate, proximal, distal) and three-dimensional (social, resource, content) construct. It shows that, in teachers' collaborative discourse, there is a complex interconnection of XK elements both within and between levels and dimensions. In this respect, it is aligned with the findings of the literature review conducted by Brianza et al. (2022), which resulted in an extended version of the TPACK, the XTPACK, showing XK as a form of "networked knowledge" (p. 729). This CHAT-based study offers a complementary theoretical perspective to apprehend XK as a dynamic network of multiple elements, providing additional information about interactions between XK elements at a systemic level. Future research should use both theoretical frameworks, XTPACK (Figure 4.2) and the activity triangle model (Figure 4.1), to better understand how XK and TPACK can contribute to the transformation of the teaching|learning activity. Relying on CHAT methodology, it would be interesting to conduct a detailed analysis to study how teachers' contextual knowledge supports the recognition of disturbances in daily practices, identification of systemic contradictions, and expression of conflicting motives, which are drivers of change (Engeström et al., 2022). Indeed, this study tends to show that the different dimensions and levels of XK exist "in a creative tension with each other", as do the other three TPACK knowledge domains (Mishra et al., 2023, p. 235). Future studies should therefore investigate how the enactment of XK fosters teachers' creativity when co-designing new TEL scenarios.

Dynamic Interconnection of XK With Other TPACK Knowledge Domains

This empirical study also shows that XK and other domains of TPACK are dynamically interconnected, to the point where some XK elements merged into TPACK knowledge when teachers co-designed. This suggests that the notion of a "dynamic amalgam" (Mishra et al., 2023, p. 235) that applies to the three knowledge domains also applies to XK as a fourth domain of knowledge. This also echoes Brianza et al. (2022), who underline that "TPACK is contextualized by being situated within contextual knowledge of a specific level as well as by relations between factors extending across levels of context" (p. 731). Further research should investigate how XK and TPACK domains interact when teachers co-design, as this dynamic combination is most likely to result in effective TEL scenarios.

Methodological Recommendations and Challenges

The theoretical considerations about the conceptual nature of XK, particularly the interconnections and relationships between different levels, dimensions, and other TPACK knowledge domains, also have implications at the methodological level. This study proposes a discourse analysis to apprehend the complexity of XK and provides a coding scheme (Tables 4.1 and 4.3) that can be used to assess teachers' XK holistically within a practice-based professional development approach. The XTPACK framework (Brianza et al., 2022)

and our coding scheme can serve as instruments to examine teachers' enactment of XK, observe the interactions between XK elements, and follow the development of XK in relation to TPACK through teachers' conversations during a formative intervention, including TEL design. This coding scheme, developed within the singular context of the PCL, represents a unique combination of XK elements (Brianza et al., 2022; Rosenberg & Koehler, 2015). Therefore, in order to improve transferability (Merriam, 2009), we have provided a detailed presentation of the context in which the PCL took place, along with an exhaustive presentation and analysis of the findings. This means that, methodologically, investigating contextual knowledge requires an in-depth analysis of teachers' conversations, from which a specific coding scheme can be developed. Furthermore, this study identified another methodological issue that future research should address: the distinction between XK and TPACK, especially when teachers co-design.

Implications and Recommendations for Practice

Fostering the Mobilization of Contextual Knowledge for TEL Design

This study provides a better understanding of how XK contributes to the design of TEL scenarios. The shift from XK to XTPACK in the teachers' discourse over the course of the PCL appears to demonstrate that to design new TEL scenarios, TPACK needs to be instantiated within the teachers' specific XK. Teachers' XK is required to guide the co-design activity in a way that aligns with their identified priorities, to inform design decisions that are appropriate to the specific parameters of their situation, and to design a new TEL scenario that provides practical changes to teaching and learning, in line with their vision for the future. CHAT methodological tools used in the PCL may then be useful in supporting the mobilization of teachers' XK. Indeed, this study suggests that visibilizing work practices through mirror material (Engeström, 2018) and theoretical modeling of the activity system (see Figure 4.21) can assist teachers in enacting their contextual knowledge to collectively design new TEL scenarios.

Context-Specific Authentic TEL Design

This study presents a TPACK formative intervention that supports teachers' learning design processes by facilitating the enactment of XTPACK dimensions within an ecological intervention. By combining expansive learning and LBD, it aligns with recommended professional development approaches in the TPACK research field (Boschman et al., 2015; Koehler & Mishra, 2005; Koh, 2019; Pareto & Willermark, 2019; Voogt et al., 2015; Voogt et al., 2016; Yeh et al., 2021), as it engages in-service teachers in a collaborative, practice-based, and context-specific authentic design problem-solving in the workplace for a long-term process of pedagogical change. This approach, which is proving beneficial for in-service teachers, as shown in this case study, is also likely to hold significant potential for enhancing pre-service teacher education. Considering that context is rarely taken into account by pre-service teachers (Nguyen & Bower, 2018; Nguyen et al., 2022), adopting a CHAT perspective when designing TEL scenarios, pre-service teachers could take a broader systemic approach (Mishra & Warr, 2021) and conduct the "deep contextual analysis" advocated by Nguyen et al. (2022, p. 8257). The PCL methodology could also be further investigated to develop structured programs that provide this type of formative intervention in schools to assist beginner teachers during their first years of teaching. Further research should then explore and compare the

relevance of combining expansive learning and LBD to support in-service, pre-service, and beginner teachers' XK.

Limitations and Future Directions

There are limitations due to the ecological perspective that has been considered in this study. Due to the small number of teachers and the specific context of this study, the results should be cautiously interpreted and transferred with prudence to other situations under similar conditions. Notably, given the unique nature of this study, it is important to consider that our coding scheme based on the XTPACK framework (Brianza et al., 2022) cannot be replicated exactly as it is. It must be modified and adapted to the specific context of the teachers participating in future studies. This is an inherent limitation of empirical research into teachers' XK in authentic settings. Furthermore, this study has examined how teachers utilized their XK and distinguished between the three phases of expansive visibilization. However, it did not explore in depth how XK was enacted according to each type of expansive learning action. Future research is required to study the development of XK within the cycle of expansive learning actions throughout the entire formative intervention (Augustsson, 2021; Engeström et al., 2013) in order to better investigate how CHAT methodology can be used for XTPACK professional development of teachers in the school workplace (Phillips, 2013). We should also note that this chapter only focuses on the mobilization of XK. While it allowed for some observations regarding the relationship between XK and TPACK in teachers' conversations, it did not thoroughly investigate this interaction. Future research should consider exploring the enactment of both XK and TPACK in similar settings. Despite the limitations, the proposed PCL intervention and the methodology for analyzing teachers' XK have significant potential for being replicated in other educational contexts. Both can support teachers in designing TEL scenarios and contribute to advance research on the enactment of XK.

CONCLUSION

The study's findings suggest that engaging teachers in an expansive visibilization process can encourage the development of their XK, which in turn contributes to their transformative process. The main expansive learning actions in the first two visibilization phases—questioning and analyzing existing practices both at the action and systemic levels—are likely to help teachers enact significant contextual knowledge elements, which, in turn, guide their design decisions. As regards the enactment of XK and teachers' developmental trajectory during the PCL, it appears that XK has evolved into XTPACK, especially when teachers were engaged in co-designing a new TEL scenario to transform their practices.

It seems that the PCL, as a collective process of professional development, is likely to foster transformative agency by incorporating the co-design of TEL scenarios within an expansive learning cycle. It empowers teachers to reshape their instructional activity system through the enactment of their XK and TPACK.

REFERENCES

Albarello, L. (2022). Chapitre 2. L'étude de cas: Pertinence et validité. In *Enquêter dans les métiers de l'humain*, Vol. 2e éd. (pp. 27–36). Éditions Raison et Passions. https://doi.org/10.3917/rp.alber.2022.03.0027

Angeli, C., & Valanides, N. (2005). Preservice elementary teachers as information and communication technology designers: An instructional systems design model based on an expanded view of pedagogical content knowledge. *Journal of Computer Assisted Learning*, *21*(4), 292–302. https://doi.org/10.1111/j.1365-2729.2005.00135.x

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). *Computers & Education*, *52*(1), 154–168. https://doi.org/10.1016/j.compedu.2008.07.006

Augustsson, D. (2020). Expansive design for teachers: An activity theoretical approach to design and work integrated learning [Högskolan Väst]. https://urn.kb.se/resolve?urn=urn:nbn:se:hv:diva-15829

Augustsson, D. (2021). Expansive learning in a change laboratory intervention for teachers. *Journal of Educational Change*, *22*(4), 475–499. https://doi.org/10.1007/s10833-020-09404-0

Boschman, F., McKenney, S., & Voogt, J. (2015). Exploring teachers' use of TPACK in design talk: The collaborative design of technology-rich early literacy activities, *Computers & Education*, *82*, 250–262, https://doi.org/10.1016/j.compedu.2014.11.010

Brianza, E., Schmid, M., Tondeur, J., & Petko, D. (2022). Situating TPACK: A systematic literature review of context as a domain of knowledge. *Contemporary Issues in Technology and Teacher Education*, *22*(4), 707–753.

Duret, C., & Romero, M. (2022). L'activité de conception de scénarios pédagogiques intégrant le numérique comme démarche créative dans la formation des enseignants. *Revue Internationale Du CRIRES: Innover Dans La Tradition De Vygotsky/CRI_SAS International Journal: Vygotsky's Heritage: Innovation in Education*, *6*(3), 46–65. https://doi.org/10.51657/ric.v6i2.51582

Engeström, Y. (2011). From design experiments to formative interventions. *Theory & Psychology*, *21*(5), 598–628. https://doi.org/10.1177/0959354311419252

Engeström, Y. (2015). *Learning by expanding*. Cambridge University Press.

Engeström, Y. (Éd.). (2018). Expansive visibilization of medical work. In *Expertise in transition: expansive learning in medical work* (pp. 167–199). Cambridge University Press. https://doi.org/10.1017/9781139023009.009

Engeström, Y. (2020). Ascending from the abstract to the concrete as a principle of expansive learning. *Psychological Science and Education*, *25*(5), 31–43. https://doi.org/10.17759/pse.2020250503

Engeström, Y., Rantavuori, J., & Kerosuo, H. (2013). Expansive learning in a library: Actions, cycles and deviations from instructional intentions. *Vocations and Learning*, *6*(1), 81–106. https://doi.org/10.1007/s12186-012-9089-6

Engeström, Y., Rantavuori, P., Ruutu, P., & Tapola-Haapala, M. (2022). The hybridisation of adolescents' worlds as a source of developmental tensions: A study of discursive manifestations of contradictions. *Educational Review*, *0*(0), 1–22. https://doi.org/10.1080/00131911.2022.2033704

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review*, *5*(1), 1–24. https://doi.org/10.1016/j.edurev.2009.12.002

Engeström, Y., & Sannino, A. (2021). From mediated actions to heterogenous coalitions: Four generations of activity-theoretical studies of work and learning. *Mind, Culture, and Activity*, *28*(1), 4–23. https://doi.org/10.1080/10749039.2020.1806328

Engeström, Y., Sannino, A., & Virkkunen, J. (2014). On the methodological demands of formative interventions. *Mind, Culture, and Activity*, *21*(2), 118–128. https://doi.org/10.1080/10749039.2014.891868

Gutiérrez, K. D., Engeström, Y., & Sannino, A. (2016). Expanding educational research and interventionist methodologies. *Cognition and Instruction*, *34*(3), 275–284. https://doi.org/10.1080/07370008.2016.1183347

Harris, J. B., & Hofer, M. J. (2017). "TPACK stories": schools and school districts repurposing a theoretical construct for technology-related professional development. *Journal of Research on Technology in Education*, *49*(1–2), 1–15. https://doi.org/10.1080/15391523.2017.1295408

Hauge, T. E. (2016). On the Life of ICT and School Leadership in a Large-Scale Reform Movement (p. 97–115). https://doi.org/10.1007/978-94-6300-648-4_6

Hill, J. E., & Uribe-Florez, L. (2020). Understanding secondary school Teachers' TPACK and technology implementation in mathematics classrooms. *International Journal of Technology in Education*, *3*(1), 1–13. https://eric.ed.gov/?id=EJ1264156

Hopwood, N., & Sannino, A. (2023). Motives, mediation and motion: Towards an inherently learning- and development-orientated perspective on agency. In A. Sannino & N. Hopwood (Éds.), *Agency and transformation: motives, mediation, and motion* (p. 1–34). Cambridge University Press. https://doi.org/10.1017/9781009153799.002

Kajamaa, A., & Hyrkkö, S. (2022). Change laboratory method for facilitating transformative agency and collective professional learning – Case from a Finnish elementary school. In M. Goller, E. Kyndt, S. Paloniemi, & C. Damşa (Éds.), *Methods for researching professional learning and development: challenges, applications and empirical illustrations* (p. 535–556). Springer International Publishing. https://doi.org/10.1007/978-3-031-08518-5_24

Kelly, M. (2008). Incorporating Context Into TPCK-Based Instructional Design. 5257–5262. https://www.learntechlib.org/primary/p/28114/

Kirschner, P. A. (2015). Do we need teachers as designers of technology enhanced learning? *Instructional Science*, *43*(2), 309–322. https://doi.org/10.1007/s11251-015-9346-9

Koehler, M., & Mishra, P. (2008). Handbook of Technological Pedagogical Content Knowledge (Tpck) for Educators. https://philpapers.org/rec/TECHOT

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, *9*(1), 60–70. https://www.learntechlib.org/primary/p/29544/

Koehler, M. J. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research*, *32*(2), 131–152.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research*, *32*(2), 131–152. https://doi.org/10.2190/0EW7-01WB-BKHL-QDYV

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. *Computers & Education*, *49*(3), 740–762. https://doi.org/10.1016/j.compedu.2005.11.012

Koh, J. H. L. (2019). TPACK design scaffolds for supporting teacher pedagogical change. *Educational Technology Research and Development*, *67*(3), 577–595. https://doi.org/10.1007/s11423-018-9627-5

Laferrière, T., Hamel, C., & Searson, M. (2013). Barriers to successful implementation of technology integration in educational settings: A case study. *Journal of Computer Assisted Learning*, *29*(5), 463–473. https://doi.org/10.1111/jcal.12034

Laurillard, D., Charlton, P., Craft, B., Dimakopoulos, D., Ljubojevic, D., Magoulas, G., Masterman, E., Pujadas, R., Whitley, E., & Whittlestone, a (2013). A constructionist learning environment for teachers to model learning designs. *Journal of Computer Assisted Learning*, *29*(1), 15–30. https://doi.org/10.1111/j.1365-2729.2011.00458.x

Lund, A., & Hauge, T. E. (2011). Designs for teaching and learning in technology-rich learning environments, *Nordic Journal of Digital Literacy*, 6, 258–272, https://doi.org/10.18261/ISSN1891-943X-2011-04-05

Maina, M., Craft, B., & Mor, Y.(Eds.) (2015). *The art & science of learning design*. Sense Publishers.

Merriam, S. B. (2009). *Qualitative research: a guide to design and implementation* (2 ed.). Jossey-Bass.

Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education*, *35*(2), 76–78. https://doi.org/10.1080/21532974.2019.1588611

Mishra, P., & Koehler, M. (2003). Not « what » but « how »: Becoming design-wise about educational technology.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mishra, P., & Warr, M. (2021). Contextualizing TPACK within systems and cultures of practice, *Computers in Human Behavior*, *117*, 106673, https://doi.org/10.1016/j.chb.2020.106673

Mishra, P., Warr, M., & Islam, R. (2023). TPACK in the age of ChatGPT and generative AI. *Journal of Digital Learning in Teacher Education*, *39*(4), 235–251. https://doi.org/10.1080/21532974.2023.2247480

Moscoso, J. N. (2019). Abductive reasoning: A contribution to knowledge creation in education, *Cadernos De Pesquisa*, *49*, 308–329, https://doi.org/10.1590/198053145255

Nardi, B. A. (1996). *Context and consciousness: activity theory and human-computer interaction*. MIT Press.

Nguyen, G. N. H., & Bower, M. (2018). Novice teacher technology-enhanced learning design practices: The case of the silent pedagogy. *British Journal of Educational Technology*, *49*(6), 1027–1043. https://doi.org/10.1111/bjet.12681

Nguyen, G. N. H., Bower, M., & Stevenson, M. (2022). The discourse of design: Patterns of TPACK contribution during pre-service teacher learning design conversations. *Education and Information Technologies*, *27*(6), 8235–8264. https://doi.org/10.1007/s10639-022-10932-w

Pareto, L., & Willermark, S. (2019). TPACK in situ: A design-based approach supporting professional development in practice. *Journal of Educational Computing Research*, *57*(5), 1186–1226. https://doi.org/10.1177/0735633118783180

Pettersson, F. (2021). Understanding digitalization and educational change in school by means of activity theory and the levels of learning concept. *Education and Information Technologies*, *26*(1), 187–204. https://doi.org/10.1007/s10639-020-10239-8

Phillips, M. (2013). Investigating in-service teachers' workplace TPACK development. *Australian Educational Computing*, 28(2). http://journal.acce.edu.au/index.php/AEC/article/view/23

Phillips, M. (2016). Re-contextualising tpack: Exploring teachers' (non-)use of digital technologies. *Technology, Pedagogy and Education*, *25*(5), 555–571. https://doi.org/10.1080/1475939X.2015.1124803

Porras-Hernández, L. H., & Salinas-Amescua, B. (2013). Strengthening tpack: A broader notion of context and the use of Teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research*, *48*(2), 223–244. https://doi.org/10.2190/EC.48.2.f

Postholm, M. B. (2015). Methodologies in Cultural–Historical activity theory: The example of school-based development. *Educational Research*, *57*(1), 43–58. https://doi.org/10.1080/00131881.2014.983723

Rantavuori, J., Engeström, Y., & Lipponen, L. (2016). Learning actions, objects and types of interaction: A methodological analysis of expansive learning among pre-service teachers, *FRONTLINE LEARNING RESEARCH*, *4*, 1–27, https://doi.org/10.14786/flr.v4i3.174

Reinius, H., Kaukinen, I., Korhonen, T., Juuti, K., & Hakkarainen, K. (2022). Teachers as transformative agents in changing school culture, *Teaching and Teacher Education*, *120*, 103888, https://doi.org/10.1016/j.tate.2022.103888

Ritella, G., & Hakkarainen, K. (2012). Instrumental genesis in technology-mediated learning: From double stimulation to expansive knowledge practices. *International Journal of Computer-Supported Collaborative Learning*, *7*(2), 239–258. https://doi.org/10.1007/s11412-012-9144-1

Rosenberg, J. M., & Koehler, M. (2015). Context and technological pedagogical content knowledge (TPACK): A systematic review. *Journal of Research on Technology in Education*, *47*(3), 186–210. https://doi.org/10.1080/15391523.2015.1052663

Sannino, A. (2015). The principle of double stimulation: A path to volitional action, *Learning, Culture and Social Interaction*, *6*, 1–15, https://doi.org/10.1016/j.lcsi.2015.01.001

Sannino, A., & Engeström, Y. (2017). Co-generation of societally impactful knowledge in change laboratories. *Management Learning*, *48*(1), 80–96. https://doi.org/10.1177/1350507616671285

Scherer, R., Siddiq, F., & Tondeur, J. (2019). The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education, *Computers & Education*, *128*, 13–35, https://doi.org/10.1016/j.compedu.2018.09.009

Schön, D. A. (1987). *Educating the reflective practitioner: toward a new design for teaching and learning in the professions* (p. xvii, 355). Jossey-Bass.

Stake, R. E. (2005). Qualitative case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research*, 3rd ed (pp. 443–466). Sage Publications Ltd.

Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S. V., Giannoutsou, N., Cachia, R., Monés, A. M., & Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and Information Technologies*, *28*(6), 6695–6726. https://doi.org/10.1007/s10639-022-11431-8

Tricot, A., & Musial, M. (2020). *Précis d'ingénierie pédagogique*. De Boeck Superieur.

Virkkunen, J. (2006). Dilemmas in building shared transformative agency. *Activités*, *03*(1). https://doi.org/10.4000/activites.1850

Virkkunen, J., & Newnham, D. S. (2013). *The change laboratory*. Sense Publishers. https://doi.org/10.1007/978-94-6209-326-3

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

Voogt, J. M., Pieters, J. M., & Handelzalts, A. (2016). Teacher collaboration in curriculum design teams: Effects, mechanisms, and conditions. *Educational Research and Evaluation*, *22*(3–4), 121–140. https://doi.org/10.1080/13803611.2016.1247725

Warr, M., & Mishra, P. (2023). Learning to see complexity: Teachers designing amidst indeterminacy. *Professional Development in Education*, *0*(0), 1–17. https://doi.org/10.1080/19415257.2023.2253821

Yeh, Y.-F., Chan, K. K. H., & Hsu, Y.-S. (2021). Toward a framework that connects individual TPACK and collective TPACK: A systematic review of TPACK studies investigating teacher collaborative discourse in the learning by design process, *Computers & Education*, *171*, 104238, https://doi.org/10.1016/j.compedu.2021.104238

Yin, R. K. (2009). *Case study research: design and methods*. SAGE.

Zhang, W., & Tang, J. (2021). Teachers' TPACK development: A review of literature. *Open Journal of Social Sciences*, *09*(07), 367–380. https://doi.org/10.4236/jss.2021.97027