Article

Sustainable Development of EFL Teachers' Technological Pedagogical Content Knowledge (TPACK) Situated in Multiple Learning Activity Systems

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Abstract: This study examined how Chinese college teachers developed their Technological Pedagogical Content Knowledge (TPACK) by situating the learning process in three interactive activity systems during teaching English as foreign language (EFL) online in China. Data were collected from teachers' diaries, in-depth interviews, and various records of online teaching. Findings indicated that teachers employed cultural artifacts, social relations, and beliefs and concepts to cope with difficulties that confronted their online teaching. They also performed sideways moves to new activities that provided systemic implications for the previous form of activity. Hence, the teachers constructed their TPACK through bi-directional learning within and between an online teaching activity system and its two interactive systems. This study highlighted the situativeness and distribution of TPACK development, and assumes significance in sustainable teacher development and further integration of information and communication technology (ICT) in English language teaching.

Keywords: Technological Pedagogical Content Knowledge; teaching EFL online; activity systems; situativeness and distribution; sustainable teacher development

1. Introduction

Information and communication technology (ICT) have been increasingly used in education to facilitate learning opportunities and enhance the quality of teaching [1,2]. Multiple studies have unraveled the positive impact of various ICT factors on students' learning process in different subject domains, claiming a significant role of ICT in students' academic performance [3–6]. Technology-enhanced teaching strategies thus have become indispensable in an educational context. However, they compound the complex teaching process, turning teaching into a more challenging profession [7]. In addition to specific subjects and pedagogical matters [8,9], teachers should learn to navigate technological resources [10] and use them properly in teaching [11], to develop the integral knowledge repertoire that is conceptualized as Technological Pedagogical Content Knowledge (TPACK) [12]. The worldwide COVID-19 pandemic and the immediately subsequent remote teaching practice have highlighted this urge. Concomitantly, teachers' learning of TPACK has become paramount in the discussion of how to integrate technology in education [13,14].

From a sociocultural perspective, individual cognition resulting from learning largely originates in the social collective mind [15]. Teacher learning and development is fundamentally shaped by engagement in the specific, goal-directed social activities, which are mediated by cultural artifacts, activities, concepts, and social relations [16]. Although the literature has revealed the significance of technology integration and demonstrated the necessity of teachers' professional development involving three knowledge bases about

subject content, pedagogical matters and ICT use [17–19], research efforts still largely concentrate on defining and developing the TPACK construct per se [11,20,21], and employing the construct to measure teachers' perception or professional competence of teaching with technology [22,23]. Only a few studies have contributed to the investigation of strategies adopted by teachers in specific domains to develop TPACK [24,25]. How teachers learn to construct and develop TPACK to improve the quality of teaching is underexplored.

Against the backdrop of preparing students for a digitalized world, language teachers feel it more urgently than teachers of other subjects in terms of technology integration in education. The issue of technological literacy has already existed in L2 classes, and become imperative when online and blended courses need to be gradually embraced as normality of students' school learning and teachers' professional education [26]. Teachers' proper use of technology in language teaching can promote student learning and help in terms of motivation [2], by allowing more access to authentic language use and culture representation and helping students develop communicative competence to make meanings through creative modes of language expressions [27]. This demands a shift from traditional instruction to a technology-enhanced paradigm that combines text, graphics/visual, audios, and videos in the same instructional program, or application. Chun, Kern, and Smith [27] contend that "understanding the affordances of these different types of technologies forms the underlying rationale for selecting particular ones for language teaching and learning" (p. 72); teachers would otherwise create a very limited and artificial learning environment for their students. However, worries and stress always come to teachers about what and how to learn for teaching with technology, to respond to new challenges arising from the shift. These questions deserve investigation as teachers' learning process and outcomes would greatly influence the quality of language teaching, ultimately impacting student learning [28]. Therefore, this study explores the complex process of teacher learning for TPACK development situated in real-world learning environments within the framework of activity systems analysis [29,30].

Drawing on data from a longitudinal multiple-case study, the paper investigates the TPACK development, if any, of eight Chinese EFL teachers when they individually worked to offer online lessons for the first time. This study aims to uncover the difficulties of online teaching and teachers' solutions, and to reveal pathways in which EFL teachers develop their TPACK-related knowing, thinking and doing.

2. Theoretical Background and Literature Review

2.1. TPACK and Related Studies

Koehler and Mishra [12] proposed TPACK (originally TPCK) based on Shulman's [8,9] construct of pedagogical content knowledge (PCK) to further include technology knowledge, a critical integral part of teachers' professional development in the new information era. This conceptual framework is widely applied to describe the knowledge bases for teachers to effectively teach with technology in specific educational contexts [18]. TPACK consists of seven components, including three main knowledge bases, three dyadic elements, and one overarching triad, i.e., technology knowledge (TK), content knowledge (CK), pedagogical knowledge (PK); and PCK, technological content knowledge (TCK), technological pedagogical knowledge (TPK) and TPACK [17,31] (see Figure 1).

The TPACK construct frames teaching competence with technology, facilitating the assessment of teachers' capability in technology integration for effective teaching. With its rapid extension across the fields of teacher professional development [18], major research efforts have been devoted to its explication and definition [17,21], validation [32,33], and even reconceptualization [34]. Only a few studies contributed to understanding teachers' TPACK in specific subject domains such as science and social sciences [13,25,35]. The issue of English language teachers' TPACK, in particular, is scarcely investigated, in spite of a high demand for them to work with the affordances of ICT tools, to "promote opportunities for all students to learn in and out of classroom" [36] (p. 9). The few existing studies concern developing TPACK-based self-assessment instruments for EFL teachers [22], applying the

instruments to measure TPACK [37], or exploring how use of specific ICT tools (e.g., digital portfolios [38]; discussion boards and blogs [39]) or technology-enhanced teaching paradigms (e.g., flipped classroom [24]) contributed to the development of teachers' TPACK as well as their competence in teaching. Unfortunately, these studies do not capture the dynamics of the knowledge construction process [40], nor are teachers' learning process and cognitive development of TPACK adequately reported.
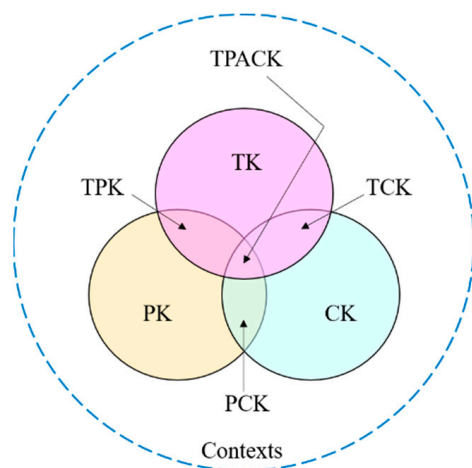
Figure 1. The TPACK construct and its knowledge (sub)sets (adapted from [17]). Note: TK: knowledge about and the ability to use all technology tools and resources. CK: knowledge about the subject matter to be taught. PK: knowledge about the methods, processes, and practices of teaching and learning. PCK: knowledge about how to arrange subject contents for teaching through specific teaching methods. TCK: understanding of how technology and content influence and constrain each other. TPK: understanding of how teaching and learning can change when particular technologies are used. TPACK: understanding that emerges from interactions among content, pedagogy, and technology knowledge.

2.2. The Situativeness of TPACK Development

As articulated by Koehler, Mishra, and Yahya [41], TPACK development is "a multi-generational process, involving the development of deeper understandings of the complex web of relationships between content, pedagogy, and technology and the contexts in which they function" (p. 740). This view calls for grounding the development in a situative view of teacher learning that is embedded in the social context. Such an external context helps generate teachers' situational behaviors that support students' ways of doing, meaning, relating, thinking, and being in technology-mediated learning spaces [10,26]. In this sense, TPACK development is not just the teachers' final acquisition of professional knowledge about technology integration, but more of a social process occurring as individual teacher-learners participate in various learning activities situated in particular physical and social contexts. As a result, the knowledge and its components develop from learning and exchange that loop between personal and collective cognitive resources [19]. This dialectical unity of individual TPACK and collective TPACK aligns with learning from a sociocultural perspective, which claims that learning emerges in the sociocultural domain, and is co-constructed among individuals and their relations within the settings and circumstances of their life/work [15]. The sociocultural perspective can enable the capture of inherent complexities that characterize teachers' learning experiences, and "make visible what those experiences ultimately lead to" [16] (p. x). Nevertheless, only recently have researchers begun to adopt a more distributive and situative view of cognition to examine TPACK development. A recent systematic literature research [19] identified 11 empirical studies (5 of which were related to either first or second/foreign-language teaching) that revealed the distribution of TPACK (sub)sets through investigation into teachers' collaborative discourse between teacher-learners and members of a learning-by-design community or

"more knowledgeable others" [19] (p. 13). However, the existing studies mostly simplify teachers' TPACK development as a product from specific activities, processes, or programs in isolation, neglecting the dynamics of the knowledge construction process. These studies fail to consider the complex and dynamic process of how it is embedded in professional lives and working conditions, and miss the interactions and/or mutual restraints that occur between and among different perspectives [42,43].

2.3. Situating TPACK Development in Activity Systems

Given the multicausal processes at work and the curvilinear nature of teacher learning (e.g., learning for TPACK development), a "complex system thinking" [44] (p. 378) is called for to investigate the dynamics of the knowledge construction, to understand under what conditions, why, and how teachers learn. In a similar manner, Mishra and Warr [45] propose that researchers need to contextualize TPACK within systems, and "descend into the complexities of systems and culture" (p. 2). The complex system thinking consists of multiple perspectives, such as the personal, situated, and distributed notions of cognition, and it can inform the interplay of elements and complex processes of teacher learning [46]. One important characteristic of teacher learning complexity is that it evolves as "a nested system involving systems within systems" [44]. For investigation into language teachers' learning as a coherent whole, Johnson [16] calls for application of activity theory [29,47] in the account for social influences and relationships, and multiple elements involved in the networks of these teachers' professional world.

As an analytical approach, activity theory takes the object-directed, artifact-mediated collective activity system as its unit of analysis [30]. It attempts to construct a holistic view of human agency in learning, the end results of human actions, the influential social factors, as well as the human activities involving all these components [48]. In the teacher learning activity system, as the *subject* (individual teacher learner or a group of teachers) acts upon the *object* (the teaching/learning goal or motive), the relations between them are mediated within the activity by other components, including *tools* and *signs* (i.e., physical and conceptual cultural artifacts), *community* (the social group to which the teacher belongs), *rules* (explicit and implicit norms and conventions affecting the activity), and *division of labor* (social status and according task assignments). These components, serving as mediating resources, either constrain or facilitate the subject's action toward the object, and consequently affect the outcome of the activity. Tensions and contradictions arising from interactions between system components, another important concept in activity theory, are "the motive force of change and development" [29] (p. 9). They can affect the subject's ability to attain the object, either making it difficult by taking a role as an obstacle, or more importantly by promoting the process of attaining the object by taking a role as an enabler [30]. The power of activity theory lies in the unit of analysis, which enables researchers to explore the situated real-world activity as a whole rather than to examine the complex yet mutually inclusive variables in it, allowing researchers to understand how each component in the activity system influences the other [48].

Based on the above rationale, this study was set up to look into the process of how in-service EFL teachers, "as learners of teaching" [16] (p. 2), learn to integrate emerging technology into their instruction online. The study is expected to help language teachers to understand how they could benefit from learning to resolve problems of online teaching, and accordingly construct and develop TPACK (sub)sets.

The research questions are as follows:

1. How did EFL teachers cope with the difficulties they encountered during online teaching?
2. How did they construct and develop their knowledge of different (sub)sets of the TPACK framework?

3. Method

We utilized a multiple-case study research design to explore how eight Chinese EFL teachers in college learned to design, prepare, enact, and adjust online lessons. A multiple-

case approach both facilitates defining patterns of variables within each case and enables cross-case comparisons [49]. The approach fits the complex phenomenon of teachers' TPACK learning based on their experiences of teaching English online in real-life contexts over a period of time (ibid.). Moreover, we employed activity systems as an analytical framework [30] to examine how teachers resolved the difficulties encountered and facilitated their TPACK construction and development.

3.1. Participants

We conducted purposive sampling by combining criterion sampling and maximum variation sampling [50] (p. 128). First, participants were recruited purposefully according to two criteria: (1) EFL teachers offering online lessons as required by their respective institutions; (2) having no experience of or formal systematic training in online teaching. Second, in selecting the participants, we followed the other two criteria: (1) Maximum variation sampling—to ensure data richness and that the stability of the pattern generalized in participant commonalities would not be subject to some variables, we selected the cases differently experienced in terms of educational backgrounds and years of teaching, from different regions of China (different regions were considered to mitigate the potential influence of imbalanced technological development in this study); (2) data reliability— we had built up a strong trusting relationship with the cases, which ensured that the information provided was true and reliable. Eight in-service EFL teachers (seven females and one male) participated in the study. The researchers had their informed consent for inclusion in every specific research practice/procedure to avoid "structural" ethical crisis, so as to guarantee the true benefits from scientific findings to the society's development [51] (p. 149). These teachers were from different institutions, five from public universities and three from private colleges, and they were required to adapt the once face-to-face courses (which were basically textbook-based, with supplementary teaching material allowed at the teachers' option) to online ones on their own. They are referred to by pseudonyms in this article. Table 1 presents a summary of the eight focal teachers' profiles.

Table 1. Participants' Profiles.

Participants	Gender	Educational Qualification	Years of Teaching	Subject Taught	Institution and Location
Daisy	Female	M.A.	23	College English (for non-English majors)	Public university, Southwest China
Stoner	Male	Ph.D. candidate	22	College English	Public university, Central China
Wang	Female	M.A.	18	College English	Public university, Southeast China
Sunny	Female	M.A.	15	College English	Public university, Central China
Grace	Female	M.A.	13	English for majors	Private college, South China
Lipia	Female	M.A.	13	College English	Private college, Southeast China
Lara	Female	M.A.	8	English for majors	Private college, East China
Ying	Female	Ph.D.	3	College English	Public university, Central China

3.2. Data Collection

We collected data mainly from: (1) diaries about online teaching experience; (2) in-depth interviews with participants. The introspective nature of these two methods makes it possible to observe internal processes in one's consciousness [50]. The diary method, in particular, allows researchers "an unobtrusive way" of looking into areas of the participants' lives that may otherwise be inaccessible and are highly relevant for "looking at tempo-

ral variation in dynamic processes" [50] (p. 157). It therefore would serve the research purposes well. In diary writing, the teachers were encouraged to describe and examine formal reflections on critical incidents, consisting of a description phase followed by an explanation phase about three aspects of their teaching practices, namely lesson planning and preparation, enactment, and adjustments. Critical reflections on teaching are a process of recognizing and analyzing assumptions that underlie teachers' thoughts and actions [52], and is conducive to exploring the process of knowledge construction and development. Each participant provided 6 teaching diaries over 8 weeks, yielding a total of 48 diaries. The semi-structured interviews were conducted via phone call or voice chatting on WeChat. The interviews probed into the teachers' learning experiences, perceptions, and applications of their TPACK (the four technology-related (sub)sets in particular). Each interview was recorded for about 1–1.5 h (nearly 9 h in total), and transcribed with participants' consent. (The data transcription and its translation from Chinese into English were conducted by the first author and verified by the second author).

Mandarin Chinese was used in both diaries and interviews, as the first language would better help the participants to reveal changes in cognition. To triangulate the data and enhance the trustworthiness, we also collected the participants' TPACK-EFL self-assessment surveys, which was adapted from Baser, Kopcha, and Ozden [22], teaching documents, self-reports of online teaching experiences, and online course evaluation by their students. The multi-source data allowed us to verify "whether and how issues/themes emerging from one type of data were also present in another type of data" [53] (p. 66).

3.3. Data Analysis

Data were analyzed by adopting an activity systems analysis following a thematic analysis [30]. For thematic analysis, we first carried out an iterative process of purposive reading and reflecting on the data. This was a crucial pre-coding move, to make sense of our first impressions of the topic under study and develop ideas that would lead us up from the messy text data to possible themes. To further identify meaningful features of data, we then conducted a more formal and structured coding process that comprised three phases, namely, initial coding, second-level coding, and selective coding [50]. In the first phase, we captured high frequency words in data by a free accessed corpus tool and compared the results with what was obtained from manual data coding. We used in vivo codes as the initial codes (i.e., the participants' words as codes). In second-level coding, we analyzed the contextual meanings of all initial codes, and clustered together similar or closely related codes to form broader categories under more abstract and broader labels. The iterative process of revisiting and modifying the higher-order pattern codes naturally led to the final phase of selective coding, in which we attempted to select core categories as central themes [50]. The thematic analysis aimed to identify teachers' difficulties, strategies, activities, and relationships among them for further investigation from an activity theory perspective.

According to Engeström [47], the learning activity nests two minimally interacting activity systems within a context, and development is also examined by interpreting how contradiction-induced changes in a past activity can affect the outcomes of new activities. On this basis, for the activity systems analysis, we first identified the unit of analysis that was embedded in the nested system of teacher learning. The core subsystem, which was determined by the most prominent theme emerging from the thematic analysis, was taken as the unit of analysis. Next, drawing upon the other emerging themes, we identified bounded/interactive subsystem(s). Then, we analyzed the systemic contradictions and difficulties within each subsystem. We performed data analysis through repeatedly examining both the results of the thematic analysis and those of the activity systems analysis and mapping them onto one another [30]. For both types of analysis, the first author did the preliminary work, and the data were examined and validated by the second author. Disagreements were resolved through discussion.

4. Findings

The analysis indicated that the unit of analysis nested within teacher learning of TPACK was online teaching activity system. This finding supported previous literature, which found that one of the most critical factors for teachers to learn to integrate technology was "their commitment to student learning", to "address student needs" [28] (p. 1331), and to achieve the instructional goals they perceive to be the most important [54]. In addition, some emerging themes related to professional development activities and the teachers' social and professional networks were situated in a bounded subsystem labeled as social resources activity system. Other themes about teachers' efforts to achieve efficacy in these activities were identified as another bounded subsystem—conceptualizing an activity system.

To drive changes and development in each activity subsystem requires resolution of the inner systemic contradictions, which in turn involves uncovering such contradictions in the first place [48]. On this basis, we captured contradictions within each subsystem and the difficulties EFL teachers faced in their learning to teach online (see Table 2), before we identified how the teachers resolved these contradictions.

Table 2. EFL teachers' difficulties and contradictions in learning to teach online.

Thematic Analysis	Activity Systems Analysis	
Difficulties	Contradictions	Activity Systems
• Struggle with new or unfamiliar technologies to aid teaching • Concern over the changed teaching/teaching management rules of virtual classes • Struggle with the influence of online technology on students' behaviors	The tension between EFL teachers' unfamiliar online classroom operations and the desired teaching effect	Online teaching activity system
• Conflict between further engagement in and withdrawal from available resources activities • Struggle to balance between the time and energy in communication with community members	The gap between the extent and depth of their participation in resources pooling and the efficacy of utilizing these resources in online teaching	Social resources activity system
• Difficulties in making sense of teaching-with-technology and TPACK-learning activities	Conceptual conflicts that emerged between theoretical ideas, personal understanding, and practical applications in teaching	Conceptualizing activity system

Table 3 presents a brief summary of the difficulties reported by each of the EFL teachers. As can be seen, these difficulties were common and some of them were even pervasive among the focal teachers in this study. In the following subsections, we illustrate them one-by-one and elaborate on the teachers' solutions within the framework of each activity system.

4.1. The Storyline of Online Teaching Activity System

As the unit of analysis, the online teaching activity system is the core subsystem embedded within the nested system of teachers' TPACK learning. The subject is the EFL teachers. The teachers' object is to fulfill teaching objectives of their respective courses through online lessons. The analysis showed that the EFL teachers were confronted by a systemic contradiction—between their unfamiliarity with online classroom operations and the desired teaching effect. All eight teachers in their diaries reported the new challenging situation, struggling with establishing (live) video/audio lectures, engaging students in online chatting rooms for classroom activities, applying new technology to classroom management, homework checking, and assessment, etc. In this case, the contradiction of the teaching activity system aggravated when new technological elements were introduced into classroom, generating multiple difficulties.

Table 3. A summary of the EFL teachers' difficulties.

	Daisy	Stoner	Wang	Sunny	Grace	Lipia	Lara	Ying
● Struggle with new or unfamiliar technologies to aid teaching	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
● Concern over the changed teaching and teaching management rules of virtual classes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
● Struggle with the influence of online technology on students' behaviors	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
● Conflict between further engagement in and withdrawal from available resources activities	Yes	Yes	Yes	Not reported	Yes	Yes	Yes	Yes
● Struggle to balance between the time and energy in communication with community members	Yes	Not reported	Yes	Not reported	Yes	Yes	Yes	Yes
● Difficulties in making sense of teaching-with-technology and TPACK-learning activities	Not reported	Not reported	Yes	Yes	Yes	Yes	Yes	Not reported

4.1.1. Difficulties in Online Teaching Activity

The most salient difficulty reported by the EFL teachers concerned their struggle with new or unfamiliar technologies to aid their teaching. Wang's experience of her pre-class struggles provided an illustration of teachers' typical problems in teaching online:

"There is a high threshold for teaching online. ... skillful operations of technologies are prerequisites. We barely had prior experience. What's worse, the platform mandated by our university didn't work well, with unstable internet connection. Without images, how could I teach English Public Speaking and activate students' interaction?". (Wang, Dairy 1)

When the new physical artifacts (i.e., online teaching platforms and various software) were included in the basic teaching tools, the tension arose. It appeared as an obstacle for the teachers to successfully conduct their classes. Wang confided that "the first week were messy" and that they were "somewhat helpless about the platform breakdown" (Wang, Dairy 1).

Another salient difficulty was induced by the dramatical change of rules in the online teaching activity system. The old rules that the teachers were relying on regarding teaching and teaching management could no longer fit the situation due to teachers' and students' physical absence in class. The teachers expressed their serious concern over it. For example, Daisy wrote:

"When I offered live video lectures (explaining the text), I could not monitor whether students were there listening attentively; when there were network slowdowns or bottlenecks, both students and I could not react to each another in time". (Daisy, Dairy 1)

This tension, if not adequately tackled, would put virtual classes beyond control, thus mitigating the effects of teaching.

A further pressing difficulty experienced by EFL teachers had to do with the division of labor (e.g., how students perform compulsory work), representing how the teachers were also struggling with the influence of online technology on students' behaviors. Lipia listed

some possible misbehaviors, such as "seeking and copying answers without independent thinking", and "challenged agency and self-discipline". She expressed her worry:

> "Without my real-time oversight, students would feel little pressured, beginning to slack off". (Lipia, Dairy 1)

Stoner also added to the concern by pointing out the trouble of keeping track of students' self-study assignments. In his words:

> "If my students didn't finish the self-study tasks, it would then be hard to carry out the Q & A sessions or maintain the goal of the task in class". (Stoner, Diary 3)

Engeström argues that the mediational role of the division of labor and established procedures "is embedded in any object-driven human activity system" [48] (p. 251). It suggests that students' poor performance in accomplishing what is assigned to them by the division of labor would inevitably influence the achievement of the object in the online teaching activity system.

4.1.2. Solutions to the Contradiction and Difficulties

These major difficulties as the internal tensions had an adverse effect on the attainment of the object. To resolve them, the teachers resorted to an array of mediating resources, such as utilizing familiar technologies, exploring compatible functions, and promoting student engagement through technology-enhanced teacher-student and student-student relationships.

The general strategic solutions to the two most salient difficulties experienced by the EFL teachers during online teaching (i.e., the teachers' struggle with new/unfamiliar technologies and their concern over the changed class rules) are to utilize familiar technologies for backup plans and explore functions of new technologies compatible with the nature of their courses/tasks. Before the term began, Sunny had filmed the course introduction (PPT show dubbed with her explanation) on a computer with a familiar software program. She then uploaded the video to the online teaching platform.

> "In case that technological problems constrained synchronous video class, my students could still access to the filmed lecture". (Sunny, Diary 1)

Her backup plan finally came to the rescue of the breakdown of live teaching, thus resolving the tension caused by integration of unfamiliar synchronous video. Notedly, her uncertainty about functions of the technology newly used prompted her to seriously consider her knowledge reserves of technology. This consideration resulted in her judgement of what appropriate known technology might also help present the course content, which led her to an action of filming mini-lectures as a backup. Sunny's judgement of both the new and familiar technologies and her following action revealed the TPACK construction in her gradual understanding in the relationship among content, pedagogy, and technology.

When facing the challenging situation of online class management, Grace, for example, became cognizant that the changed rules for teaching could also change her conduct in virtual classrooms. She found that, instead of literally being present in every class to do text explanation in person (which had to be repeated in every of the three classes), videos of her instructions would be workable in virtual classrooms, because "the part of elaborate text explanation required little teacher-student interaction" (Grace, Diary 3). She thereby learnt how to use software for quick recording and shot some short videos about her explanation of knowledge points from the text. She then uploaded these videos to a shared digital teaching platform for all her three classes as pre-class tasks. Her integrated English course involved many videos of text explanation. She acknowledged that:

> "This new practice was more adaptable to my course than the traditional ones". (Grace, Diary 3)

As a result, Grace actively involved students in tasks in the flipped classroom, including Q and A, and checking students' learning progress. It showed that she gradually

developed knowledge about how the characteristics of the courses and tasks could determine the selection and application of technologies, and how use of particular technology could afford teaching, and evolve pedagogy and the presentation of content. In this manner, she acquired knowledge of the four technology-related TPACK (sub)sets.

To mitigate the constraining effect of technology on students' expected classroom performance, the teachers mostly drew upon mediating the teacher-student and student-student relationships through mediational artifacts and in particular technological means. Technology-supported group discussion was a good choice by Ying. She asked students to conduct discussion via QQ (an online social media platform) groups, and then nominated a delegate to report to the whole class online.

> "Team leaders were responsible for every member. Screenshots providing evidence of teamwork also motivated participation. Without face-to-face pressure, some timid or passive students behaved confidently in group discussion. It worked ever better online than in traditional classes". (Ying, Diary 1)

Another participant, Stoner, found that the traditional practice of dictation tests in online classroom turned out to be a boring and intimidating job and also might fail to prevent students from cheating. He thereby resorted to a website to create word puzzles of new vocabulary in each lesson. This task involved students actively reviewing, analyzing, and even negotiating. Stoner acted as a designer and organizer, freeing the class from his dictatorship. "My students all liked it," he expressed a relief (Stoner, Diary 4 and interview). It appeared that both Ying and Stoner understood the mutual influence between technology's utility and subject content or teaching skills and methods in the new scene, which was a sign of TPACK construction.

After the teachers' efforts to turn tensions into motives for them to attain the object, the outcome of the online teaching activity in the teachers' TPACK construction was produced. Meanwhile, the interaction between the agency of these teachers and the systemic contradiction (i.e., their unfamiliarity with technology use and their uncertainty about the final effects of online teaching) further spawned bounded activity subsystems—the social resources activity system and the conceptualizing activity system. They are "new qualitative stages and forms of activity emerg[ing] as solutions to the contradictions of the preceding stage of form" [29] (p. 91).

4.2. The Storyline of Social Resources Activity System

Social resource issues were bound to happen when most of these teachers were motivated and aspired in varying degrees to resolve the aggravated contradiction of the online teaching activity. This emerged as an expansive transformation accomplished in a collective journey "when the object and motive of the activity are reconceptualized to embrace a radically wider horizon of possibilities than in the previous mode of the activity" [47] (p. 137). This phenomenon echoes with the claim that good self-regulators expand their knowledge and cognitive competencies [55]. In this activity system, the subject is still the EFL teachers. Their object is to obtain and apply more useful technologies to online classes so as to facilitate the accomplishment of their teaching objectives. For this object, the teachers participated (either voluntarily or passively) in many resourceful social activities to gather useful information as to how to teach online, expanding the scope of teacher learning to social context. When the teachers acted upon this object, they were confronted by the systemic contradiction arising from the gap between the extent and depth of their participation in resources pooling and the efficacy of utilizing these resources in online teaching.

4.2.1. Difficulties in Social Resources Activity

In this online-teaching-activity-bounded subsystem, a major difficulty reported by the EFL teachers in their learning for TPACK was their indecision between further engagement in and withdrawal from available resource activities outside the teaching activity. These eight teachers all reported their access to courses, lectures, classroom observations, sem-

inars, etc., concerning technology in teaching or how to use supplementary multimedia materials. However, they sometimes refrained from more active involvement due to their doubt in the value of some of the resource activities or the worth of more participation than needed. For example, Lara mentioned that considering her students' English level, she gave up using the video resources accompanying the textbook, because:

> "Those videos are time-consuming, with high information density, and too professional and difficult for students". (Lara, Diary and & 2)

> Wang also expressed her reservations about the how-to training program of the online teaching platform jointly offered by her university and the technology company, critiquing the program as "unsatisfactory" and the platform as "with limited functions". (Wang, Interview)

A second major problem experienced by the teachers was induced by the open nature of the community of this activity system. When more personnel were involved in this activity system, the teachers had to battle for a balance between the time and energy in their communication with the personnel and the enabling resources and opportunities these community members would bring to their professional development in demand. Daisy confided that she would withdraw from participation, provided that the information learned could suffice the basic teaching needs, because:

> "Teachers always have heavy work load. No one really has much time or energy for it". (Daisy, Interview)

> Wang further explained this idea:

> "I think teaching should focus on the subject content. Just keep the auxiliary means to what is needed . . . . If more advanced technologies are to be applied, I would rather have technical professionals do it for me". (Wang, Interview)

Apparently, for EFL teachers to invest in personal resources that enable them "to exploit promising fortuities" in their professional development of online teaching [55] (p. 12), it is wiser to foster strategic participation in social resources activities, which would help balance time and energy for development in teaching.

4.2.2. Solutions to the Contradiction and Difficulties

The analysis showed that the EFL teachers mainly adopted purposive participation as a strategy to redress the immediately above-mentioned major difficulties in this activity system. To be more specific, they employed problems concerning technology application in online teaching, incentives for teaching with more applicable technical means, and more experienced and competent professionals as mediators of their purposive participation.

In the collective resource activities, problem-oriented action enabled these teachers to accurately target meaningful information, with which they learned how to apply certain technology to solve the problems for improved teaching practices. Lipia recalled that:

> "Students suggested inclusion of some videos which would better capture their attention after the first week's live audio classes. I then asked colleagues to recommend available websites or software for easy access to the downloads". (Lipia, Diary 1 and Interview)

Likewise, Grace consulted the course team members and "chose an applicable software program for video-shooting" (Grace, Interview), to address the problem of repeated live teacher explanations in her three online classes. In their cases, problem orientation helped improve the accuracy of learning from the social resources pooling for technology application in teaching, which was conducive to the increase of technology-related knowledge in TPACK.

In addition, incentives in their teaching careers were another important orientation reported by these teachers. A grant, project, or teaching contest were regular incentives for

them to be actively involved in learning in this regard. Sunny commented on her first prize of the teaching contest as "inspiring", prompting her:

> "To search for technical means, which were more applicable to the pedagogical content matter and the use of which were more readily acceptable to students". (Sunny, Interview)

> This incentive-mediated action in her later educational praxis was proof of her developed understanding of the interplay among pedagogy, content, and technology. Moreover, more experienced people were potent mediators of their purposive participation. These types of purposeful personal interactions were in essence models of inquiry-based learning for TPACK development. These interactions created "alternative structural arrangements" of shared-object-oriented collective resources pooling and utilizing activity "that support sustained dialogic mediation" [16] (p. 6) between the teacher learners and their mentors (i.e., more experienced others). The dialogic mediation, in turn, urged the learners to reflect on their outdated knowledge, and construct new perceptions about the mutual influence of pedagogy, content, and technology. Meanwhile, it provided emotional support for these teachers to reduce their fear of "learning to do online teaching only on one's own". (Sunny, Interview)

Sustained purposive participation in social resources activities enabled the EFL teachers to maintain continued yet reasonable investment of time and effort to trade for resources in self-renewal that supported professional proficiency under the ever-changing conditions of teaching with technology. In this way, the object had been constantly transformed until the outcome of this activity system was finally molded—the teachers' improved perceptions about decision making, application, and effects of technology during teaching (i.e., the teachers' TPACK development). However, as members of the community within this activity system, the EFL teachers had to perform their roles and coordinated activities "with a high sense of efficacy" [55] (p. 16). The demand for such an efficacy then bred the next subsystem of activity, the conceptualizing activity system.

4.3. The Storyline of Conceptualizing Activity System

Data analysis of systemic contradictions and difficulties in the former two activity subsystems facilitated our understanding of how EFL teachers made sense of teaching with technology and learning of TPACK before, after and while engaging in educational activities [56]. To achieve efficacy in the activities, the EFL teachers-as-learners (i.e., the subject) had to make sense of what they have learnt, what they learnt means, and how they could apply it, which denoted the formation of beliefs (i.e., the object), and transformed their beliefs into generic categories which provided them with an orienting basis for action in later professional life (i.e., the outcome). The aggregation of sense-making tasks was the conceptualizing activity system, in which "contradictions and connections between theoretical ideas, personal understandings, and practical applications" [56] (p. 360) of teaching with technology emerged within and beyond online classrooms. For example, Sunny thought highly of her experiences of online teaching:

> "I found that the seemingly obscure theoretical underpinnings, such as task-based approach, blended teaching, flipped classroom, in fact closely knitted with our pedagogical practices. Online teaching . . . has reduced the teacher's authoritativeness, and placed students in the center, encouraging their initiative to explore and acquire new knowledge". (Sunny, Diary 5)

Sunny began to establish connections between teaching practices and her prior knowledge of theories. Her articulation of "task-based approach, blended teaching, flipped classroom", "the teacher's authoritativeness", and "students . . . center", the sign of development in her meta-knowledge of how technology afforded teaching and learning, was the result of her conceptualizing activity.

In addition, those sense-making tasks offered opportunity for the teachers to deepen their understanding of teaching with technology, which was demonstrated in the claim made by Grace:

> "I do not favor the lectures merely on technology. I feel as if they stay at the "Shu" (technique) level. But once in a lecture, the lecturer dealt with "Tao" (philosophy), enlightening me to the idea of how teaching is elevated when integrated with technology". (Grace, Interview)

Mediated by the two concepts "Shu" (technical skills) and "Tao" (the potential of teaching integrated with technology), Grace was able to reflect on the difference between use of technology for its own sake and proper technology integration. This reflection showed her improved TPACK in regard to how technical means could afford/constrain teaching and wield influence in an educational praxis. It led her to shoot short videos of teacher explanation and assign video-viewing as pre-class tasks to students, which resulted in the realization of a flipped classroom during online teaching. It therefore could be argued that the continued synergy of reflection and praxis in sense-making tasks has made teachers' beliefs conceptualizing tools for transforming their teaching with technology, and contributed to the incorporation and the subsequent internalization of TPACK concepts. Mediated by the conceptualizing activities, the teachers gained increased self-regulation of learning, and a following performance in teaching and higher cognitive functions were thus realized [57].

5. Discussion

The study has examined the processes wherein the EFL teachers resolved the difficulties encountered in practicing online teaching and facilitated the construction and development of their TPACK. Our analysis of data revealed that, to overcome the three major difficulties confronted the online teaching, the EFL teachers not only appropriated available cultural tools and social relations as mediational means, but also performed two subsequent forms of activities as coping strategies that provided systemic implications for the previous form of activity. In the meantime, TPACK development occurred via bi-directional learning: vertical movement through learning to resolve difficulties within the online teaching activity as well as sideways movement to the two bounded activity subsystems. The full cycle of teacher learning of TPACK is presented in the three interactive activity subsystems, as shown in Figure 2.
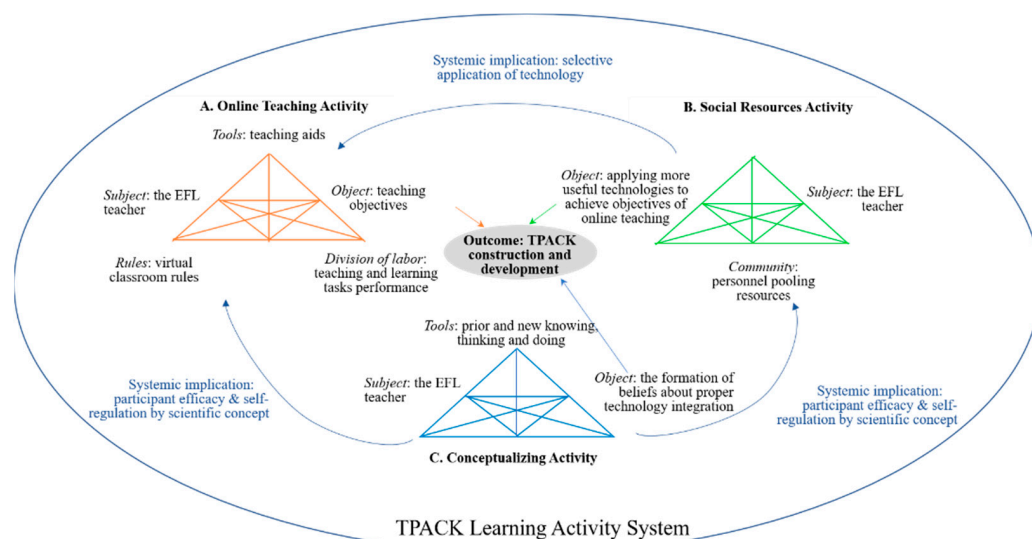
Figure 2. Interactive activity subsystems nested within teacher learning of TPACK through online teaching.

5.1. Strategies for Coping with Online Teaching Difficulties

While teachers were learning to improve their knowledge of online teaching, they experienced different struggles in three interactive subsystems embedded in their learning activity. We identified systemic contradictions as follows: the tension between the teacher's unfamiliarity with online classroom operations involving technology use and the desired effect of teaching, their struggle for a balance between investment of time and energy in participation in resources pooling and the efficacy of utilizing these resources in online teaching, as well as conceptual connections/conflicts that emerged between theoretical ideas, personal understanding, and practical applications in teaching. These contradictions manifested themselves in the inner tensions, i.e., the difficulties experienced by the teachers within the subsystems of TPACK learning activity system. Specifically, in the online teaching activity system, teachers' most reported difficulties were their unfamiliarity with new technologies, the changed rules of teaching/teaching management in the virtual site, and students' possible misbehaviors resulting from technological constraints. Subsequently, in the social resources activity system, the inner difficulties pointed to the teachers' doubts about their engagement in some resourceful activities outside the teaching environment, and about whether relevant personnel would afford the enabling resources and opportunity. Meanwhile, in the conceptualizing activity system, teachers had difficulty in making sense of some practice in teaching with technology and the related learning.

Though these contradictions and difficulties "may disrupt change and development, they may also facilitate change and development" [53] (p. 69), provided that the EFL teachers would reverse the adverse effects. Primarily, the EFL teachers' solutions emerged while they were trying to optimize their online teaching conducts, to obtain the object of the online teaching activity system (i.e., the teaching objectives). This was aligned with Mishra and Koehler's [31] proposal of "learning technology by design" (p. 1034) and Voogt et al.'s [18] review that involvement in technology-enhanced lesson planning and enactment was a major strategy for teachers' TPACK development. Initially, the teachers worked to solve problems confronting online teaching that arose from any change in terms of the teaching tools, the classroom rules, and teachers' and students' divided compulsory labor due to the introduction of new technology. For this end, the teachers interacted with available mediating cultural tools and social relations, including familiar technologies for backup plans, more compatible functions of new technologies, and technology-enhanced teacher-student and student-student relationships. In doing so, they gained the outcome of knowledge construction on different (sub)sets of TPACK (e.g., the developing understanding of Sunny, Ying, and Stoner with regards to the interaction between technology and content and/or pedagogy) (see Module A. in Figure 2).

Furthermore, this outcome, together with the teachers' collaborative envisioning for better solutions, stimulated their deliberate collective change to generate the "historically new form of the societal activity" [47] (p. 137), the social resources activity subsystem. Although participation in the social resources activities was another coping strategy to problems of online teaching activity system, new problems were generated when the teacher subjects engaged with the boundless community that pooled together resources pertinent to technology integration in teaching. In this bounded subsystem, the major strategy by the EFL teachers was purposive participation in resourceful technology-related social activities, which were mediated by the authentic problems in teaching, career incentives, and competent social others. The purposive participation was believed to better facilitate the attainment of the object of this subsystem, obtaining and applying more yet appropriate technologies to achieve online teaching objectives. Meanwhile, this purposive participation also reflected their careful selection of technical means to be applied in teaching (i.e., systemic implication) and the outcome of their improved perceptions of TPACK (e.g., Lipia and Sunny sought out applicable technical means to meet students' needs or to improve teaching effectiveness) (see Module B. in Figure 2).

Moreover, another subsystem nested within teacher learning of online teaching, the conceptualizing activity, was generated to provide participant efficacy (i.e., systemic im-

plication) as a further solution to reconcile contradictions in the previous two activity subsystems. The teachers generally performed sense-making tasks where theoretical ideas, personal understandings, and practical applications, both old and new (i.e., their prior and new knowledge, thinking, and doing regarding technology integration) were utilized as cognitive tools to mediate the conceptualizing activity. In the end, such higher-order-thinking activity resulted in the outcome of the developing/developed scientific concepts of technology integration (i.e., TPACK) (e.g., Sunny's understanding of connection between blended teaching, flipped classroom, and her online teaching practices; Grace's proposal of the notion of "Tao" for proper technology integration in teaching). This conceptual knowledge is in turn internalized for self-regulation in learning activities (i.e., systemic implication) (see Module C. in Figure 2).

5.2. Pathways for TPACK Construction and Development

The findings shed light on the learning opportunities for and bi-directional learning by the EFL teachers. The teachers engaged in three interactive activity subsystems contextualized in a complex macro learning activity system, to dynamically develop their TPACK when they appropriated available mediating resources to resolve problems within each subsystem. The learning opportunities initially emerged in the online teaching activities when the teachers learned to deal with some technical means that were "prerequisites" for online teaching (Wang, Dairy 1). Subsequently, they became aware that technology use wielded an influence on the presentation of subject content and the choice of teaching methods, processes, and practices, and vice versa. So, their proper strategies, such as use of substitute known technology, usable functions of new technology, and technology-enhanced relationships, helped make teaching practices with technology "more adaptable to my course than the traditional ones" (Grace, Diary 3). To wit, "learning technology by design" during online teaching [31] (p. 1034) not only led to the teachers' acquisition of TK, but also to the elevated understanding of how TK interworked with CK and PK—TCK, TPK, and TPACK, resulting in their higher levels of online teaching competence. This is a sign of vertical movement of cognitive functioning [57].

Furthermore, our data showed that the teachers did not stop at this stage of learning and development, minimally meeting their online teaching objectives. They actively expanded the scope of their learning and continued "a sideways move" [47] (p. 154) to social resources activities. In this larger-scope activity subsystem, the teachers further engaged with learning opportunities when they purposively interacted with richer resources and more competent professionals that mediated both their action and mind, to make teaching with technology "more applicable to the pedagogical content matter" and "more readily acceptable to students" (Sunny, Interview). The teachers' agency, demonstrated by this voluntary sideways learning, endorsed their conscious selection of technical means being more applicable to teaching. Their selective technology application in turn suggested an update of their TPACK—their awareness of the value of proper technology and its added value from interacting with content and pedagogy and the constraints on one another.

Meanwhile, to enhance the efficacy in the previous two activity subsystems, the participants continued to clarify and modify their previous knowing, thinking, and doing. This led to another sideways move to the conceptualizing activities, where the teachers rejected the idea that teaching with technology was a technical skill, but embraced the gradual formulation of some scientific concepts, e.g., "task-based approach, blended teaching, flipped classroom" (Sunny, Diary 5); "Tao" for "how teaching is elevated when integrated with technology" (Grace, Interview). To sum up, the teachers' bi-directional transformative learning finally arrived at the construction of scientific concepts with high relevance to technology integration with teaching, which will provide an orienting basis for them to regulate their future TPACK learning and performance in teaching.

6. Conclusions and Implications

This study examined the process of teacher learning for TPACK development through online teaching via the lens of activity theory, and identified the teachers' difficulties and patterns of learning during their engagement in the online teaching activity subsystem and two bounded activity subsystems (i.e., social resources activities and conceptualizing activities). The findings indicate that engaging learning in the three interactive activity subsystems is a process rich in learning opportunities, in which the teachers promoted bi-directional learning and development of TPACK through their interaction with system components in the form of cultural artifacts, social relations, and beliefs and concepts. It has multiple implications for teacher development and language education.

First, the study reveals the nature of TPACK development as a dynamic cognitive process, thus highlighting the need to examine its situativeness and distribution in teachers' real-world professional and social contexts. Teacher educators or teacher development programs in this regard are suggested to include authentic/simulation teaching-with-technology activity/tasks as the main venue for TPACK learning. Other activity systems that are nested within the learning activity and bounded with the teaching activity are also necessary to be incorporated in the professional development programs so as to expand the scope of learning. Moreover, the quality of tools and scientific concepts concerning technology integration, and the quality of collective TPACK (e.g., through collaborative discourse) can mediate teachers' personal TPACK, thus needing to be purposefully structured in professional development programs so as to facilitate the attainment of the object of the learning activity.

Second, the findings of this study suggest that activity systems analysis lives up to the call for complex system thinking for understanding teacher learning [44]. Since systemic contradictions and inner difficulties are the motive force of development, the identification of difficulties/contradictions is a good starting point of learning. Meanwhile, situating TPACK learning in activity systems, teachers can know what resources to resort to for a mediating effect by examining and interacting with the system components.

Thirdly, as it is a small-scale case study, the patterns of teacher learning for TPACK development represent some universal principles by examples of how to learn new paradigms of teaching with technology and solve the concomitant problems. This study therefore assumes significance in promoting further integration of ICT in English language teaching and the sustainable development of teacher profession and of language education as a whole.

The limitations of our study still need attention. First, as a case study involving eight EFL teachers, its generalization is constrained to similar contexts. Second, while how student learning is supported serves as the most important criterion for evaluating teaching and teacher development [16], future research should examine the outcomes of TPACK learning from students' perspective, such as students' attitudes towards their teachers' competence in TPACK and the effects of student learning.

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