



Investigating teachers' participation patterns in online teacher professional development: what is the relationship between participation frequency and participation quality?

Min Chen^{1,2} · Yanqiu Liu^{3,4} · Harrison Hao Yang⁵ · Yating Li^{2,4} · Chi Zhou^{1,4} 

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Abstract

Online teacher professional development (OTPD) opportunities are made available to teachers and draw increasing research attention. As the key characteristics of teachers' participation in OTPD, the frequency and quality of participation are increasingly concerned. However, the relationship between teacher participation frequency and participation quality is still unclear. Addressing this problem not only helps reveal teachers' participation patterns in OTPD, but also provides support for promoting teachers' online professional learning and improving OTPD organization and management. To identify teachers' participation patterns and the relationship between participation frequency and participation quality in OTPD, this study analyzed 5,064 log records of 415 teachers using lag sequential analysis, t-test, and Chi-square test. The findings indicated that teachers preferred shallow participation behaviors, such as sharing resources and experience, and seldom carried out deep participation/engagement behaviors (e.g., proposing knowledge topics, establishing teaching and research practices). Teachers with higher participation frequency had lower participation quality in OTPD and tended to repeat shallow participation behaviors. Finally, the study proposed some suggestions for better supporting teachers' participation in online professional development, such as strengthening the links between information sharing activities, knowledge construction activities, and teaching and research practices.

Keywords Online teacher professional development · Teacher participation · Participation frequency · Participation quality · Lag sequential analysis

1 Introduction

Online teacher professional development (OTPD), which enhances the collaboration and interaction among teachers (Prenger et al., 2017; Zhang & Liu, 2019), is a popular way to promote teachers' professional competence (Greenhow & Askari, 2017). Online communities and networks remove the limits of learning space (Wu & Nian, 2021; Yang & Chen, 2020), support asynchronous interaction and knowledge sharing (Powell & Bodur, 2019), and offer more authentic, flexible and personalized chances for teachers' professional development (Zhang et al., 2017). Especially during the COVID-19 pandemic, OTPD becomes a must because face-to-face approaches are restricted (UNESCO, 2020).

To promote OTPD, many countries have developed online professional development programs (Jansen in de Wal et al., 2020; Ke et al., 2019; McChesney & Aldridge, 2021). Teachers are encouraged to participate in these programs and complete certain online learning tasks or online learning time. For example, the United States has developed the e-Mentoring for Student Success (eMSS) program to provide online expert mentoring for new teachers (Alyson, 2012). The program required new teachers to participate in online discussion sessions, complete teaching inquiry practices, and finish a learning outcomes summary. However, due to lack of time, heavy workload, or lack of effective support, many teachers regard online professional development programs as tasks (Ataş et al., 2021; Botham, 2018). In this case, whether teachers have conducted effective professional learning, what is the participation pattern and participation quality of teachers in OTPD are still not clear. Clarifying the above issues can deepen the understanding of the current situation and patterns of OTPD, help to effectively manage online professional development programs, and promote teacher development.

As the key characteristics of teachers' participation in OTPD, the frequency and quality of participation are increasingly concerned. For example, some scholars analyze teachers' participation frequency in online learning activities, including the number of videos watched, the frequency of participation in forums, and the number of interactions with others, to explore teachers' participation status in OTPD (Beisiegel et al., 2017; Bonafini, 2017; Zhang et al., 2017). In addition, in order to improve the quality of teachers' participation in OTPD, some researchers explored incentive and intervention strategies that could improve teachers' efficacy (Ansley et al., 2021; Reeves & Chiang, 2018) and learning performance (Biasutti et al., 2019; Jiménez & O'Shanahan, 2016; Ma et al., 2021). Although there have been various studies related to teachers' participation in OTPD. The relationship between teacher participation frequency and participation quality is still unclear. Addressing this problem not only helps deepen the understanding of the mechanism of OTPD, but also provides support for promoting teachers' online professional learning and improving OTPD organization and management. Therefore, this study aimed to analyze teachers' participation patterns and the relationship between participation frequency and participation quality in OTPD, based on the process data of online professional development. Three research questions guided the present study:

(1) What are the distribution characteristics of various behaviors demonstrated by the teachers in OTPD?

- (2) What is the correlation between teachers' participation frequency and participation quality in OTPD?
- (3) What is the difference between frequent users and seldom users in OTPD?

2 Literature review

2.1 Online teacher professional development

Constrained by convenience, flexibility, and sustainability, traditional face-to-face teacher professional development activities cannot meet all the needs of teachers (Powell & Bodur, 2019). A new way is needed to promote teacher professional development such as teachers' competence in teaching with technology (Bragg et al., 2021; Prestridge, 2017). In this case, OTPD was proposed as a process where teachers can collaborate and communicate with others, solve teaching problems and grow together through online communities (Atapattu et al., 2019; Lucas et al., 2021; Powell & Bodur, 2019; Reisoğlu & Çebi, 2020).

To promote effective online professional development, educational research has made great progress in enhancing our knowledge and understanding of OTPD. Some researchers explored the role of OTPD in teacher development and found that OTPD enables teachers to improve their content knowledge, teaching beliefs, self-efficacy and teaching practice (Bragg et al., 2021; Wong et al., 2022). For instance, Erickson et al. (2012) found that teachers who participated in online professional development programs acquired knowledge and improved ability to apply research-based practices. Marquez et al. (2016) also reported that online teacher professional development programs were beneficial to the improvement of teachers' classroom management skills and self-efficacy. Philipsen et al. (2019) found that online teacher professional development played an essential role in facilitating teacher reflection. In these studies, the importance of OTPD for teacher development has been well documented. In-depth analysis of teacher participation in OTPD would help deepen the understanding of the mechanisms of OTPD and promote the effective development of teachers' professional abilities.

2.2 Teacher participation frequency and participation quality in OTPD

Teacher participation frequency has been considered as an important indication that reflects performance in OTPD (Beisiegel et al., 2017; F. C. Bonafini 2017; Vu et al., 2014). Teacher participation frequency mainly refers to the number of times teachers participate in various learning activities of online professional development, such as the number of videos watched and assignments submitted (Li & Baker, 2018), the frequency of visiting online learning platforms, and the number of times to participate in community peer activities (Tsiotakis & Jimoyiannis, 2016). Some scholars have studied the current situation of teacher participation frequency in OTPD. For example, Zhang et al. (2017) analyzed the frequency of teachers' interactions with other teachers on the OTPD platform and revealed that teachers' participation frequency was low and the interaction network was low reciprocal. Satar and Akcan

(2018) investigated teachers' online participation by calculating their weekly online forum posts.

Teacher participation quality is defined as the investment of energy, concentration, and effort in OTPD (Henrie et al., 2015; Kuh, 2001), which is increasingly emphasized as a critical factor for impacting professional learning and development performance (Li & Baker, 2018; Robson, 2018). High participation quality in OTPD enables teachers to have a deeper and more solid understanding of the knowledge they have learned (Trust et al., 2016). Therefore, high participation quality is a predictor of continuing motivation, commitment, and overall performance (Shernoff & Hoogstra, 2001). Considering the positive role of participation quality in teacher professional development, scholars have focused on the quality of teacher participation (Ma et al., 2021; Prestridge, 2017). For example, Chen et al. (2009) analyzed teachers' online synchronous discussions on mathematics teaching and found that most messages were at the level of simple information processing involving less cognitive and metacognitive skills, and the quality of teachers' participation was low. Prestridge and Tondeur (2015) investigated the quality of teachers' participation in OTPD by analyzing teachers' reflective discussions and constructive dialogues related to teaching and research practices.

Although both teacher participation frequency and participation quality focus on teacher participation and are important in OTPD. They focus on different aspects of teachers' performance in OTPD. Specifically, participation frequency is more focused on the quantity of teachers' online behaviors, while participation quality is more concerned with teachers' information processing and knowledge construction behind their online behaviors (Heflin et al., 2017). Although there are some findings regarding the current status of participation frequency and participation quality in OTPD, the current understanding of teacher participation patterns in OTPD still needs to be further deepened. Clarifying the relationship between teacher participation frequency and participation quality can deepen the understanding of the participation patterns and mechanisms of OTPD, support the organization and management of teacher professional development, and promote efficient teacher professional development. Therefore, this study aimed to address this research gap and provide useful recommendations for guiding teachers, as well as for the effective implementation of OTPD activities.

3 Method

3.1 Participants

The participants were a group of teachers ($n=415$) voluntarily participating in the online teacher training program. Among them, 136 are male teachers (32.77%), and 279 are female teachers (67.23%). The number of primary school teachers was 257 (61.93%), and that of secondary school teachers was 158 (38.07%). They were very familiar with the online professional learning platform and process and had rich online learning experiences. This study was supported by the provincial departments responsible for ICT in education. The results of this study would not have any

negative impact on participating teachers. To maintain participant confidentiality and privacy, anonymization procedures were implemented for all personal information collected in the study.

3.2 Online professional learning environment

In this study, teachers' online professional learning environment was the *Online Professional Development Platform*, as shown in Fig. 1. Teachers could communicate, interact, collaborate and share educational resources with others. Teachers' online professional learning activities mainly include the following three categories: information and resources sharing, discussion and communication, and collaborative teaching and research practice. Specifically, teachers could share personal resources and experiences (e.g., articles and lesson plans) and comment on shared information; discuss and communicate with peers on specific knowledge topics, including asking questions, providing solutions or ideas, showing agreement or disagreement; carry out collaborative teaching and research practice with peers (e.g., collaboratively constructing lesson plans and courseware).

3.3 Data collection

Based on the three important activities of online teacher professional development (i.e., information and resources sharing, discussion and communication, collaborative teaching and research practice), the platform automatically recorded seven operation behaviors of teachers. Table 1 shows the details of teachers' operation behaviors. For example, in the collaborative teaching and research practice activities, teachers entered the *collaborative teaching and research practice* module and clicked "Create" button to create a theme-based teaching and research practice. Then this type of behavior was recorded as "establishing teaching and research practices". Other teachers could click "Join" button to participate in the teaching and research practices. Then this type of behavior was recorded as "participating in teaching and research practices". During the online teacher professional development process, a



Fig. 1 The homepage of the online professional development platform

Table 1 Description of teachers' operation behaviors

Activities	Operation behaviors	Description
Information and resources sharing	Sharing resources and experience	Share personal experience, resources, and educational materials
	Commenting on shared information	Comment on shared educational resources and experiences, and information exchange
Discussion and communication	Proposing knowledge topics	Propose a topic for discussion or group work, such as asking questions
	Discussing on knowledge topics	Discuss knowledge topics with others, including providing solutions or ideas, showing agreement or disagreement
Collaborative teaching and research practice	Establishing teaching and research practices	Create theme-based teaching and research practices, such as studying how to effectively carry out flipped classrooms
	Participating in teaching and research practices	Participate in established teaching and research practices
	Summarizing opinions or feelings	After participating in teaching and research practices, express personal views or feelings, such as summarizing experience, and evaluating strengths or weaknesses of practical activities

Table 2 Classification of teacher operational behaviors based on different types of participation

Participation types	Behavior	Code
Shallow participation	Sharing resources and experience	SRE
	Commenting on shared information	CSI
Deep participation /engagement	Proposing knowledge topics	PKT
	Discussing on knowledge topics	DKT
	Establishing teaching and research practices	ETRP
	Participating in teaching and research practices	PTRP
	Summarizing opinions or feelings	SOF

total of 5,064 log records of the participants over six months were obtained, and each of them included user ID, operation behaviors, object ID, and data & time.

3.4 Analysis procedure

Analyzing log data can find out teachers' behavior and explain how they conduct online professional learning (Zarzour et al., 2020). To investigate teachers' participation patterns in OTPD and to respond to the three research questions, this study classified teachers' operational behaviors into different participation types and then analyzed the user log data using t-test, chi-square test, and lag sequential analysis.

3.4.1 Classification of Teachers' Operation Behaviors in OTPD

To analyze teachers' participation status in OTPD, this study classified teacher participation into two different types, and then divided teachers' operation behaviors into two categories based on the type of participation (as shown in Table 2). The details of

the procedure to map the various operation behaviors to different participation types are as follows.

Firstly, based on the previous research (Tuck, 2013), participation types can be divided into two categories: shallow participation and deep participation (or called engagement). Shallow participation refers to people taking part in something in very defined and determined ways, which is occasional and is designed to have little structural impact. For example, individuals share information they have comprehended to others. On the contrary, deep participation (or called engagement) refers to people helping define the scope of discussion, the rules of engagement, and the structure of relationships. For example, individuals collectively design curriculum, develop processes of brainstorming and decision-making. Therefore, this study classified teacher participation into two different types: shallow participation and deep participation (or called engagement).

Then, according to the definition of shallow participation (as mentioned above), shallow participation included sharing information. Therefore, teachers' operation behaviors of "information and resources sharing activities" belong to shallow participation. Specifically, combining the information of Table 1, the behaviors of "sharing resources and experience" and "commenting on shared information" belong to shallow participation.

Finally, the engagement theory indicated emphasizing collaboration, project-based assignments, and doing projects with a realistic focus are three primary means to accomplish engagement (Kearsley & Shneiderman, 1998). Meanwhile, deep participation (or called engagement) refers to people helping define the scope of discussion, the rules of engagement, and the structure of relationships. The above descriptions of engagement and deep participation are consistent with the descriptions of discussion and communication activities and the collaborative teaching and research practices in OTPD. Therefore, teachers' operation behaviors of "discussion and communication activities" and "collaborative teaching and research practice activities" belong to engagement (or called deep participation). Specifically, combining the information of Table 1, the behaviors of "proposing knowledge topics", "discussing on knowledge topics", "establishing teaching and research practices", "participating in teaching and research practices", and "summarizing opinions or feelings" belong to deep participation.

3.4.2 Data analysis

To answer the first research question, the frequency distributions of various behaviors and the time series characteristics of each type of participation (i.e., shallow participation and deep participation/engagement) was calculated. Specifically, we imported the log data into SPSS 26.0 software, and then used "Analyze → Descriptive Statistics → Frequencies" functions to calculate the frequency and proportion of each behavior, representing the frequency distributions of various behaviors. Then, based on the behavior frequency and date, used the plot function of python 3.8 software to draw a time series diagram. This diagram represented the time series characteristics of each type of participation (i.e., shallow participation and deep participation/engagement).

Concerning the second research question, we first defined the participation frequency and participation quality of each teacher in OTPD. In this study, the participation frequency of each teacher was represented using their sum frequency of behaviors in OTPD (as shown in Eq. 1). According to the define of participation quality and deep participation as mentioned in the previous section (Sect. 2.2 and Sect. 3.4.1), the participation quality of each teacher was represented by their proportion of deep participation/engagement behaviors in all behaviors (as shown in Eq. 2). Then, a scatter plot was used to preliminarily explore the relationship between teacher participation frequency and participation quality, and a sample *t*-test was used to confirm whether teachers at different levels of participation frequency (i.e., frequent users and seldom users) had significantly different participation quality.

$$P_f = Num(SRE) + Num(CSI) + Num(PKT) + Num(DKT) + Num(ETRP) + Num(PTRP) + Num(SOF) \quad (1)$$

$$P_q = (Num(PKT) + Num(DKT) + Num(ETRP) + Num(PTRP) + Num(SOF)) / P_f \times 100\% \quad (2)$$

Here P_f refers to the participation frequency of one teacher in OTPD, P_q refers to the participation quality of one teacher in OTPD. $Num(SRE)$, $Num(CSI)$, $Num(PKT)$, $Num(DKT)$, $Num(ETRP)$, $Num(PTRP)$, $Num(SOF)$ respectively represent the frequency of behaviors SRE, CSI, PKT, DKT, ETRP, PTRP, SOF.

Regarding the third research question, behavior distribution and behavior transition of frequent users and seldom users were investigated to explore the difference between frequent users and seldom users. Chi-square test was used to investigate the difference in behavior distribution between frequent users and seldom users. Furthermore, lag sequential analysis can detect behavioral sequence patterns that are not due to random effects (Arias-Pujol & Anguera, 2020; Bakeman & Gottman, 1997). Therefore, this study applied lag sequential analysis to investigate behavior transition of frequent users and seldom users by Generalized Sequential Querier 5.1 software. In the lag sequence analysis process, we first calculated the behavioral transition matrix represented by z-scores. In the behavioral transition matrix, only z-scores higher than 1.96 indicate that there is a significant transition relationship between the two behaviors (Bakeman & Gottman, 1997). And then we constructed the behavioral transition diagram, which only showed the significant behavioral transitions.

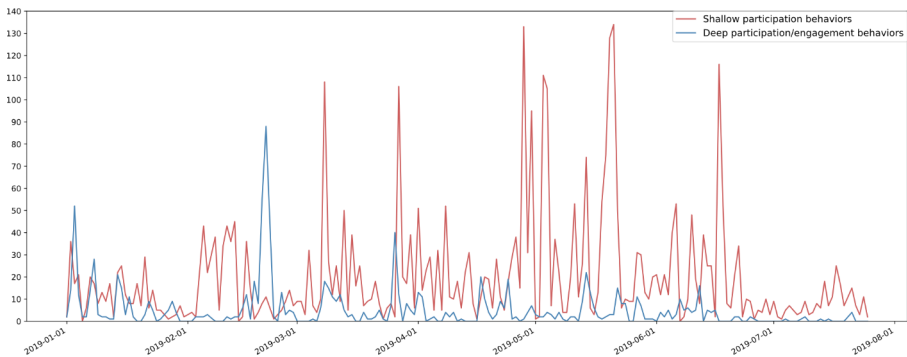
4 Results

4.1 The distribution characteristics of teachers' behaviors in OTPD

Table 3 shows the frequency and percentage of each behavior over the six months. Results showed that the percentage of SRE (sharing resources and experience) was the highest (61.7%), followed by CSI (18.1%, commenting on shared information) and DKT (14.1%, discussing on knowledge topics). However, SOF (summarizing opinions or feelings), PKT (Proposing knowledge topics), PTRP (participating in teaching and research practices), and ETRP (establishing teaching and research prac-

Table 3 Frequency distribution of online behaviors

Category	Behavior	Frequency	Percentage
Shallow participation	Sharing resources and experience (SRE)	3126	61.7%
	Commenting on shared information (CSI)	917	18.1%
Deep participation / engagement	Proposing knowledge topics (PKT)	70	1.4%
	Discussing on knowledge topics (DKT)	714	14.1%
	Establishing teaching and research practices (ETRP)	49	1.0%
	Participating in teaching and research practices (PTRP)	70	1.4%
	Summarizing opinions or feelings (SOF)	118	2.3%

**Fig. 2** Time series characteristics of teachers' online behaviors

tices) only occurred occasionally, ranging from 1.0 to 2.3%. These results indicated that teachers often adopted shallow participation behaviors (79.8%) rather than deep participation/engagement behaviors (20.2%).

To further understand the characteristics of the two categories of behaviors adopted by teachers at different times, a time series diagram was drawn, as shown in Fig. 2. The frequency of teacher behaviors showed a trend of increasing first and decreasing later, and teachers had more behaviors in the middle stage. In terms of each category of behaviors, shallow participation behaviors occurred throughout the whole stage and were mainly concentrated in the middle stage. Deep participation/engagement behaviors mostly appeared in the pre-mid stages and almost disappears in the subsequent stage.

4.2 The relationship between teachers' participation frequency and participation quality

We used the total frequency of online behaviors and the proportion of deep participation/engagement behaviors to represent the participation frequency and participation quality of each teacher. Then a scatter plot was used to show the participation frequency and participation quality of each teacher in OTPD (see Fig. 3). The results indicated that teachers with low participation frequency (i.e., seldom users) usually had higher levels of participation quality. In contrast, teachers with high participation frequency (i.e., frequent users) tended to have lower levels of participation quality.

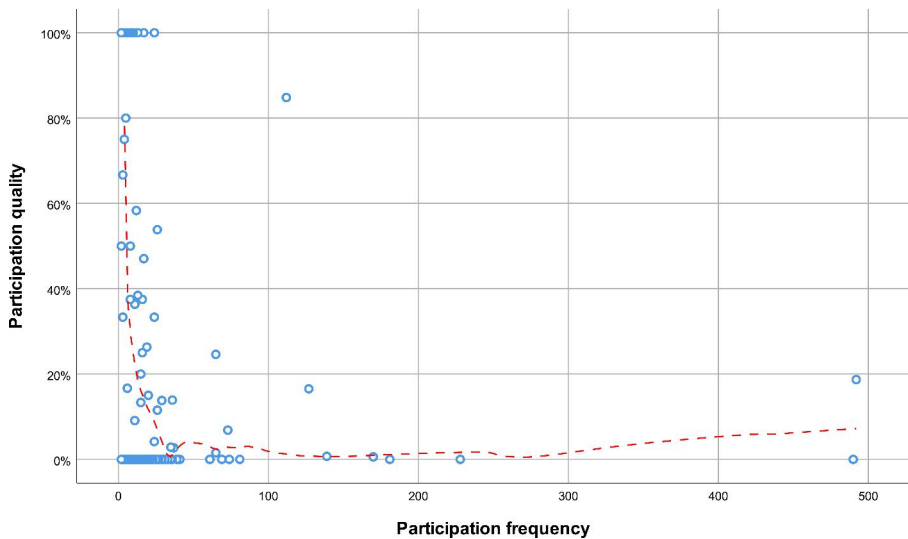


Fig. 3 A related scatter plot of participation frequency and participation quality

Table 4 Results of the sample *t*-test analysis

Group	Mean	SD	<i>t</i>
Frequent user group	16.11%	0.31	-10.44***
Seldom user group	70.54%	0.45	

Notes: *** $p < 0.001$

To confirm the difference in participation quality between teachers with different participation frequency, teachers were divided into the frequent user group (i.e., teachers with high participation frequency) and the seldom user group (i.e., teachers with low participation frequency). Teachers were arranged in descending order of behavior frequency, and then the extreme grouping method (Kelley, 1939) was used to select the first 27% of the teachers as the frequent user group ($N=112$) and the last 27% of the teachers as the seldom user group ($N=112$). Teachers' participation quality in the frequent user group and the seldom user group was compared using *t*-test. As Table 4 shows, compared with the seldom user group, teachers' participation quality in the frequent user group was significantly lower ($t = -10.44$, $p < 0.001$). This result implies that teachers who frequently participate in online professional development have lower levels of participation quality.

4.3 The difference between frequent users and seldom users in OTPD

4.3.1 Comparisons of behavior distribution between frequent user and seldom user groups

This research explores the difference between frequent users and seldom users by analyzing behavior distribution and behavior transition of frequent user and seldom user groups. The results of Chi-square test revealed a statistically significant difference between the online behaviors of frequent user and seldom user groups in OTPD

($\chi^2=560.23, p<0.001$). The comparisons of behavior distribution between the two groups are shown in the Table 5. Except for CSI and ETRP behaviors, there are significant differences in other behaviors. Specifically, the frequent user group focused on SRE and PKT behaviors than the seldom user group, and the seldom user group preferred DKT, PTRP, and SOF behaviors more than the frequent user group. In other words, compared with the seldom user group, the frequent user group preferred to share resources and experience and propose knowledge topics, especially share resources and experience (accounting for 71.64%).

4.3.2 Comparisons of behavior transition between frequent user and seldom user groups

To investigate teachers' behavior trajectories in OTPD, we analyzed the transition of teachers' behaviors in frequent user and seldom user groups. Table 6 shows that 12 behavioral transitions of the frequent user group and four behavioral transitions of the seldom user group reached statistical significance.

As shown in Fig. 4, four behavioral transitions (SRE \rightarrow SRE, CSI \rightarrow CSI, DKT \rightarrow DKT, PTRP \rightarrow ETRP) was common between the two groups, indicating that all teachers in the two groups tended to share resources and experience, comment on shared information, and discuss on knowledge topics. Moreover, after participating in teaching and research practices, teachers would express their opinions and feelings. Regarding the seldom user group, the frequency of these four behavioral transitions is not much difference (their z-scores are almost the same). As for the frequent user group, although they have more behavioral transitions (e.g., SOF \rightarrow PTRP, PKT \rightarrow DKT, PKT \rightarrow ETRP), their behavioral transitions are mainly concentrated in SRE \rightarrow SRE (z-score=52.81), CSI \rightarrow CSI (z-score=54.61), and DKT \rightarrow DKT (z-score=54.21). And the behavior transition with the smallest z-score is CSI \rightarrow PTRP (z-score=2.57). These results indicated that it was difficult for the frequent

Table 5 Comparisons of behavior distribution between the frequent user group and the seldom user group

Behavior	Frequent users	Seldom users	Total
Sharing resources and experience (SRE)	2966 (71.64%) _a	22 (9.82%) _b	2988 (68.47%)
Commenting on shared information (CSI)	724 (17.49%) _a	44 (19.64%) _a	768 (17.60%)
Proposing knowledge topics (PKT)	70 (1.69%) _a	0 (0.00%) _b	70 (1.60%)
Discussing on knowledge topics (DKT)	256 (6.18%) _a	125 (55.80%) _b	381 (8.73%)
Establishing teaching and research practices (ETRP)	45 (1.09%) _a	0 (0.00%) _a	45 (1.03%)
Participating in teaching and research practices (PTRP)	18 (0.43%) _a	17 (7.59%) _b	35 (0.80%)
Summarizing opinions or feelings (SOF)	61 (1.47%) _a	16 (7.14%) _b	77 (1.76%)
Total	4140 (100%)	224 (100%)	4364 (100%)

Notes: the subscript letters a, b: the same letters indicate that there is no significant difference in online behaviors between the two groups; on the contrary, there are significant differences in online behaviors between the two groups

Table 6 Behavioral transition table of the teachers in the frequent user group and the seldom user group

Group		SRE	CSI	PKT	DKT	ETRP	PTRP	SOF
Frequent user group	SRE	52.81*	-40.79	-8.62	-24.47	-1.38	-4.25	-7.64
	CSI	-41.11	54.61*	-3.16	-6.65	-2.58	2.57*	-0.67
	PKT	-9.25	-3.54	29.55*	6.41*	2.64*	-0.5	-1.02
	DKT	-23.9	-6.65	5.02*	54.21*	-1.67	0.17	-1.94
	ETRP	-2.04	-2.61	1.49	-0.4	17.22*	-0.39	0.49
	PTRP	-5.77	-1.32	-0.56	-1.08	-0.44	-0.25	29.23*
	SOF	-5.83	1.04	-1.01	-1.4	-0.8	8.54*	19.06*
Seldom user group	SRE	10.58*	-1.68	0	-4.03	0	0	-1.43
	CSI	-1.78	10*	0	-5.27	0	0	-2.2
	PKT	0	0	0	0	0	0	0
	DKT	-3.82	-5.56	0	10.02*	0	0	-4.73
	ETRP	0	0	0	0	0	0	0
	PTRP	-1.48	-2.15	0	-4.64	0	0	10.21*
	SOF	0	0	0	0	0	0	0

Notes: * $p < 0.05$

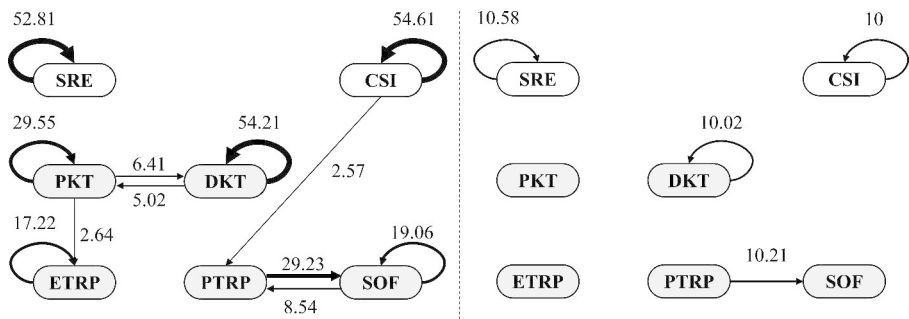


Fig. 4 Behavioral transition of the teachers in the frequent user group (left) and the seldom user group (right). Notes: the white-filled boxes represent shallow participation behaviors, and the gray-filled boxes represent deep participation/engagement behaviors

user group to convert shallow participation behaviors (SRE and CSI) into deep participation/engagement behaviors (PKT, DKT, ETRP, PTRP, and SOF).

5 Discussion

This study aimed to understand teachers’ participation patterns in online teacher professional development and the relationship between participation frequency and participation quality. Some findings are worth further discussion. The results showed that teachers preferred shallow participation behaviors (e.g., sharing resources and experience accounting for 61.7%), and seldom carried out deep participation/engagement behaviors (e.g., proposing knowledge topics accounting for 1.4%, establishing teaching and research practices accounting for 1.0%). Consistent with previous research findings, many teachers only exchange information in online communities

(Neuman & Cunningham, 2009; Tschannen-Moran & McMaster, 2009). In addition, shallow participation behaviors (information and resources sharing) mainly happened in the middle stage, and deep participation/engagement behaviors (discussion and communication, collaborative teaching and research practice) mainly took place in the pre-mid stage. This result aligns with the finding in online discussions that teachers mainly expressed their opinions in the middle period rather than in the later period (Redmond, 2015). This may be because teachers are not motivated enough to continue participating in these activities (Ketelaar et al., 2014). To improve this phenomenon, formulating effective strategies to enhance teachers' willingness to continue participation in OTPD is important (Tondeur et al., 2018).

It was found that teachers with high participation frequency (i.e., frequent users) had lower levels of participation quality than teachers with low participation frequency (i.e., seldom users). We further compared the difference in behavior distribution and behavior transition between the frequent user and seldom user groups. The results of behavioral distribution analysis showed that the frequent user group preferred to share resources and experience and propose knowledge topics, while the seldom user group preferred to discuss knowledge topics, participate in teaching and research practices, and summarize opinions or feelings in these practices. This implied that teachers who frequently participated in online teacher professional development were keen to share personal experience, resources, and educational materials. Similarly, Zhang et al. (2017) found that information sharing and comparison were the most-frequent behaviors in online collaborative learning activities. This may be because, teachers tend to perform simple assignments such as sharing information with other teachers instead of investing additional time and energy in higher level of cognitive thinking, like thinking critically about new theories or ideas, and engaging in in-depth discussions with other teachers about knowledge building and teaching practices (Chen et al., 2009).

Then, the behavior transition analysis showed that the frequent user group of teachers mainly inclined to share resources and experience (SRE), comment on shared information (CSI) and discuss on knowledge topics (DKT) repeatedly. And, it was difficult for the frequent user group to convert shallow participation behaviors (SRE and CSI) into deep participation/engagement behaviors. Similarly, Huang et al. (2019) analyzed user interaction patterns in online discussions and found that participants tend to adopt similar behaviors when others shared information. This may be due to the characteristics of high continuity and concentration of the same type of behaviors. Therefore, to promote teachers to further explore and generate deeper participation behaviors, it may be necessary to adopt some strategies to enhance the relevance of various activities in OTPD (Hou et al., 2009).

6 Implications

6.1 Theoretical implications

In order to promote a deeper understanding of the underlying mechanisms of online teacher professional development, this study analyzed the patterns of teacher partici-

pation in OTPD and the relationship between the participation frequency and participation quality. This study provides new insights into teachers' online professional development and makes two main contributions to previous research.

First, this study applied engagement theory to identify teacher participation patterns in OTPD and revealed the relationship between the participation frequency and participation quality. As a widely recognized theory, engagement theory is often intended to be a conceptual framework for technology-based learning, with an emphasis on meaningful learning, and has been used in empirical studies on a range of topics (Annamalai et al., 2023; McKenzie et al., 2022; Xing et al., 2022). Despite the theory's widespread use in a variety of settings, research on teachers' online professional development remains limited. This study expands the application field of engagement theory and contributes to the further development and application of this theory.

Second, this study bridges a research gap in the existing literature by exploring the relationship between the participation frequency and participation quality in OTPD. Previous studies have evaluated the frequency and quality of teacher participation in online professional development (Zhang et al., 2017; Trust et al., 2016; Ma et al., 2021). However, few studies have focused on the patterns of teacher participation in OTPD and the relationship between the participation frequency and participation quality of teachers. More importantly, this study conducts an in-depth analysis of the behavioral distributions and behavioral transitions of frequent and seldom used teacher groups, which has not been explicitly explored in previous studies. These research findings provide new insights into the mechanisms of online teacher professional development, and serve as references for promoting teacher professional development.

6.2 Practical implications

The findings of this study shed light on teachers' participation patterns and the relationship between participation frequency and participation quality, which can inform educators how to better support teachers to participate in online professional development. Furthermore, this study found that teachers who participated frequently in OTPD had lower level of participation quality. Therefore, teacher educators should pay attention to the differences between teachers at different levels of participation frequency.

First, given the repeated shallow participation behaviors (information sharing) adopted by frequently participating teachers, it is important to construct some mechanisms or strategies to increase the transition rate of sharing and commenting on information to deep participation/engagement behaviors. Appropriate behavioral interventions and enhanced links between information sharing activities and other activities (e.g., collaborative teaching and research activities) can be beneficial (Liu et al., 2016). For example, after information sharing behaviors, provide group oriented learning tasks to lead to more diversified and in-depth interaction (Peng et al., 2016), and use peer assessment mechanisms to promote knowledge co-construction and sharing (Hou et al., 2009).

Second, as for teachers with seldom participation, teacher educators can design diverse and flexible activities to increase their willingness to participate in online professional development (Ke et al., 2019). It is necessary to design strategies to stimulate teachers to take more deep participation/engagement behaviors that will lead to high-quality instructional activities in their teaching practices (Chen et al., 2019). The result showed that teachers' deep participation/engagement behaviors gradually decreased in the middle stage of online professional development activities. Therefore, it would be necessary to provide supports before they stop participating in knowledge construction or collaborative teaching and research activities in OTPD. For example, teacher educators can provide scaffolding for teachers' learning tasks to reduce teachers' perceived task difficulty (Zhang et al., 2019). Proactive school policy support, positive organizational climate, formulating collective action, self-regulation and interpersonal interaction among members may be effective approaches (Chen et al., 2022a; Lu & Churchill, 2014; Wu et al., 2022). Also, some studies have attempted to improve teachers' participation by improving online environment and activity (Beach, 2017; Lee & Brett, 2015) and establishing performance evaluation and feedback mechanisms (Xing & Gao, 2018).

7 Conclusion

This study aimed to identify teachers' participation patterns concerning their online behaviors in OTPD. The results suggested that teachers preferred shallow participation behaviors (e.g., sharing resources and experience), and teachers who frequently participate in online professional development had the lower levels of participation quality. To explore this phenomenon, the behavior distribution and behavior transitions of frequent user and seldom user groups of teachers were analyzed. The results indicated that that frequent user group of teachers tended to share information repeatedly, which was considered as shallow participation behaviors. Moreover, frequent user group of teachers rarely transitioned information sharing behaviors into other deep participation/engagement behaviors (e.g., participating in teaching and research practices). These findings help deepen the understanding of teachers' participation patterns of OTPD and provide some implications for improving the quality and efficacy of OTPD.

This study has some limitations. First, the sample and data of this study are not representative enough, which may limit the generalizability of our findings. Future research could expand the scope of sampling, such as conducting larger sample size, cross-country, and cross-cultural studies. Finally, this study analyzed teachers' participation and engagement only through their online behaviors. Future research could use more approaches (e.g., interviews, observations) to conduct more in-depth studies of the reasons for the differences between frequent users and seldom users in OTPD.

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Data Availability The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare that they have no financial or personal relationships which may have inappropriately influenced him in writing this article.

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Authors and Affiliations

Min Chen^{1,2} · Yanqiu Liu^{3,4} · Harrison Hao Yang⁵ · Yating Li^{2,4} · Chi Zhou^{1,4}

✉ Chi Zhou
zhouchi@ccnu.edu.cn

- ¹ Educational Informatization Strategy Research Base of Ministry of Education, Central China Normal University, Wuhan 430079, Hubei, China
- ² Research Center of Science and Technology Promoting Educational Innovation and Development, Center for Strategic Studies Science and Technology Committee of Ministry of Education, Central China Normal University, Wuhan 430079, Hubei, China
- ³ Hubei Research Center for Education Informatization Development, Key Research Institute of Humanities and Social Sciences of Hubei Province, Central China Normal University, Wuhan 430079, Hubei, China
- ⁴ National Engineering Research Center for E-Learning, Central China Normal University, Wuhan 430079, Hubei, China
- ⁵ School of Education, State University of New York at Oswego, Oswego 60543, USA