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# Exploring secondary school teachers' TPACK for video-based flipped learning: the role of pedagogical beliefs

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## Abstract
Video-based flipped learning (VFL) has become a popular form of flipped learning. However, teachers' technological pedagogical content knowledge (TPACK) for video-based flipped learning is still under-explored. A TPACK-VFL questionnaire for assessing teachers' TPACK for VFL was developed and validated with both EFA and CFA in this study to fill the research gap. After instrument development and validation, a total of 211 secondary school teachers' TPACK for VFL, their pedagogical beliefs, and the role of teacher pedagogical beliefs on their TPACK for VFL were explored in this study. The results showed that the secondary school teachers in this study generally expressed sufficient confidence in their TPACK for VFL. They tended to have strong learner-centered pedagogical beliefs and moderate teacher-centered pedagogical beliefs. Besides, compared with the senior high school teachers, the junior high school teachers showed significantly higher confidence in their technological pedagogical content knowledge (TPACK) for VFL ($p < 0.05$). This study also found that the teachers' learner-centered pedagogical belief was significantly correlated with their content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK) ($p < 0.05$). In contrast, their teacher-centered pedagogical belief was significantly correlated with their TCK, TPK, and TPACK ($p < 0.05$). Cluster analysis was conducted based on the teachers' pedagogical beliefs, which yielded three groups: the Learner-centered Group, the Double-emphasis Group, and the Neutral Group. A series of ANOVA confirmed that the three groups of teachers significantly differed in their CK, PK, PCK, and TPACK ($p < 0.05$), indicating that teachers' pedagogical beliefs played a role in their TPACK for VFL. A series of post hoc analyses further revealed that, in general, the teachers in the Double-emphasis Group (i.e., those teachers who held both strong learner-centered and teacher-centered pedagogical beliefs) showed better TPACK for VFL.

Extended author information available on the last page of the article

**Keywords** TPACK · Flipped learning · Secondary teachers · Pedagogical beliefs

## 1 Introduction

In recent years, there has been an increasing interest in the implementation of flipped learning in various educational settings (e.g., Bauer-Ramazani et al., 2016; Challob, 2021; Ekici, 2021; Mamum et al., 2021; Meyliana et al., 2021; Tanner & Scott, 2015). According to its broad definition, flipped learning is "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (Flipped Learning Network, 2014, P.1). In other words, the key to flipped learning model is the reversal of transmission of knowledge from in-class to out-of-class time. Flipped learning also transforms conventional teacher-centered didactic approaches into a balance of learner-centered and teacher-centered approaches.

### 1.1 Video-based flipped learning in secondary education

A prevalent pedagogical flipped learning model is "video-based flipped learning" (VFL). The VFL can be viewed as a pedagogical response to recent technological, social, and pedagogical changes. First, Bishop & Verleger, 2013) stated that the rapid development of emerging technologies (e.g., Youtube, vodcast, podcast, and web 2.0) and mobile devices had provided more access to students' out-of-class technology-based learning by applying the flipped classroom approach. Second, evident changes among students' technology-enabled social practices are also conducive to the VFL. Students nowadays are likely to be prosumers of technologies, and they have a solid inclination to stay connected (Li et al., 2014; Meyliana et al., 2021; NG et al., 2021). Consistent with the emphasis of the VFL, students can be provided with ample opportunities to presume (i.e., consume and produce) information during out-and-in-class learning activities. Third, the VFL appears to match the recent pedagogical changes. Although constructivist-oriented teaching is becoming the norm in education, traditional teaching is still deemed as necessary by teachers and learners (Blair et al., 2016; Limniou et al., 2018; Sang et al., 2009). Both types of teaching are employed in the flipped classroom (Bishop & Verleger, 2013). In the VFL, short video lectures are viewed by students at home before class, and complex problem-solving activities are implemented in class with teachers and peers' support (Seery, 2015; Shyr & Chen, 2018). The integration of online and offline (face-to-face) interaction (Keppell et al., 2011) has been touted to promote student-centered learning.

With the prevalence of VFL, more and more research has been conducted to examine the effectiveness of VFL learning. Due to the flexibility of course design, most of the VFL research in earlier stages has been conducted in higher education contexts (e.g., Gunduz & Akkoyunlu, 2019; Molnar, 2017; O'Flaherty & Philips, 2015). Research in higher education has proven that the advantages of VFL outperformed its drawbacks (e.g., Clark, 2015; Kostaris et al., 2017). More and more VFL research has been conducted at the secondary level in recent years. These studies were majorly conducted in several subject domain learning contexts, including mathematics (e.g., Bhagat et al., 2016; Clark, 2015; Kirvan et al., 2015), physics (e.g., Atwa et al., 2016; Kettle, 2013), Chinese language arts (e.g., Tseng et al., 2016; Wang, 2016), English language (e.g., Yang & Chen, 2020), and technology education (e.g., Kostaris et al., 2017; Lee & Lai, 2017). Most of the research investigated the effectiveness of VFL on secondary learners' learning achievement (e.g., Chao et al., 2015; Huang & Hong, 2016; Wang, 2016), as well as their attitude (e.g., Bhagat et al., 2016) and motivation (e.g., Huang & Hong, 2016) toward VFL (Atwa et al., 2016; Kirvan et al., 2015). Also, the VFL helped improve the face-to-face interactions between students and teachers in class (Chao et al., 2015; Cheng, 2017; Schultz et al., 2014; Yang & Chen, 2020). Despite that, the number of VFL studies in secondary schools has been increasing recently; however, compared to higher education, the VFL studies in secondary schools occupy only a tiny portion of the literature (Ekici, 2021; Lo & Hew, 2017a, b). Therefore, more VFL studies conducted in the secondary context are recommended.

Undoubtedly, teachers play an essential role in the successful implementation of VFL (Bhagat et al., 2016; Chao et al., 2015). However, it should be noticed that the VFL research on teachers is still scarce. In particular, only a few VFL research has reported secondary teachers' challenges and difficulties in teaching with VFL. For example, Grypp and Luebeck (2015) reported that teachers might not comprehend the core value of VFL and were not accustomed to the approach. Also, it was found that when preparing VFL instruction, teachers might experience difficulties in finding videos that match what they want their students to learn (Chen, 2017), and teachers need extra time to prepare the instructional videos (Snyder et al., 2014). Thus, it seems that secondary school teachers may need more assistance in teaching with VFL. Therefore, to help them implement VFL, more relevant VFL research on teachers is suggested to be conducted.

### 1.2 Teachers' TPACK for VFL

The early success of flipped classrooms mainly was from higher education settings in engineering schools (Bishop & Verleger, 2013). The instructors are content experts who have years of teaching experience and are concerned about students' learning. In other words, the early success of VFL is based, at least in part, on the high pedagogical content knowledge (PCK) of the instructor. However, not many studies have addressed how teachers design teaching in VFL contexts (e.g., Phillipson et al., 2015; Quinn & Kennedy-Clark, 2015). It suggests that more research could be conducted to explore relevant issues regarding designing teaching with VFL pedagogy. In particular, the form of knowledge that teachers employ and create in the design and implementation process of VFL is precious for the sustained development of the VFL. The current technological pedagogical content knowledge (TPACK) framework is thus employed in this study to analyze the teachers' perceived levels of confidence. Research on teachers' confidence was based on Bandura's theory of self-efficacy which states that one's success depends on his or her innate ability to achieve goals (Bandura, 1977). Previous research has indicated that the teachers' confidence and self-efficacy are associated with their commitment to developing instruction (Xi et al., 2020; Avalos, 2011; Saudelli & Ciampa, 2016; Tschannedn-Moran & Hoy, 2001). In particular, teachers who consider themselves have higher confidence in integrating technology into teaching are more likely to use technology for teaching design and teaching instruction, and thus they may create a better quality of lessons (e.g., Kumar et al., 2008). Besides, teachers' sense of efficacy (i.e., their confidence) also directly connects with students' learning performances on academic tasks (Tschannen-Morgan & Hoy, 2001). Nonetheless, enhancing teachers' confidence is just the first important step for teachers to engage in the tedious work of continuous improvement of lesson design. The effectiveness of instruction is also dependent on a host of other factors, such as students' online learning habits and adequate access to technology and teachers' having adequate time and support to perfect their VFL lesson design. Thus, exploring teachers' confidence in implementing VFL with the TPACK framework in this study is a significant first step towards better VFL design.

Some studies have revealed that teachers often lack adequate knowledge to integrate technology into their teaching practice (Koehler et al., 2014). In pursuit of models to enhance teachers' knowledge and expertise, Shulman (1986) proposed that teachers need a particular type of knowledge combined with content knowledge and instruction. The framework is coined as pedagogical content knowledge (PCK). However, PCK did not highlight the role of technology. With the widespread use of technology used in class, Mishra and Koehler (2006) proposed a widely accepted technological pedagogical and content knowledge (TPACK) framework that has taken the knowledge of technology into account. The TPACK framework consists of seven types of teacher knowledge. The fundamental forms of knowledge are content knowledge (CK), referring to any subject-matter knowledge that a teacher is responsible for teaching, pedagogical knowledge (PK), referring to teacher's instructional designs, teaching strategies, and methods to promote students' learning, technology knowledge (TK) referring to knowledge about how to handle and work on computer software and hardware (Lin et al., 2013; Mishra & Koehler, 2006). The three forms of knowledge (CK, PK, and TK) are then shown as overlapping circles in a Venn diagram (Chai et al., 2013). From the Venn diagram, four other forms of knowledge can be derived from the overlapping areas among CK, PK, and TK. They are technological content knowledge (TCK), referring to the integration of content knowledge and technology knowledge, pedagogical content knowledge (PCK), referring to the interaction between content knowledge and pedagogical knowledge, technological pedagogical knowledge (TPK), referring to the combination of technology and instructions, and finally technological pedagogical content knowledge (TPACK). TPACK is one kind of synthesized and transformed knowledge derived from the aforementioned six TPACK construct components (Wu & Wang, 2015). The TPACK framework has been recognized as an essential theoretical foundation for technology integration research, and TPACK research in which the TPACK framework is explicitly used in exploring teachers' teaching with technology has been flourishing (e.g., Angeli & Valanides, 2009; Wu, 2013; Koh et al., 2014; Mishra & Koehler, 2006; Polly, 2011). Since the implementation of VFL involves the use of technology to support students' learning, there is no denying that teachers' technological pedagogical content knowledge (TPACK) is crucial for the implementation of VFL. However, a relevant study focusing on exploring teachers' TPACK for VFL is still not available.

### 1.3 Teachers' pedagogical belief and its possible correlation to TPACK for VFL

As aforementioned, teachers' pedagogical beliefs could be another critical factor for successful VFL implementation. Teachers' pedagogical beliefs are "preferred ways of teaching" (Bardakci & Alkan, 2019; Teo et al., 2008). Typically, teachers' pedagogical belief encompasses teacher-centered and learner-centered pedagogical belief (Chai et al., 2009). In addition, recent studies have demonstrated that teachers' pedagogical belief was a critical indicator of technology use in the classroom (e.g., Bardakci & Alkan, 2019; Getenet, 2017; Liu, 2011). Even if teachers have sufficient TPACK for VFL, their pedagogical beliefs could be related to their willingness to change their conventional teaching practices into VFL (Lim & Chai, 2008; Ertmer, 2005; Petko, 2012). Therefore, for TPACK researchers, the relationships between TPACK and teachers' pedagogical beliefs have always been crucial issues.

Other studies have explored the relationship between teachers' general TPACK and their pedagogical beliefs (Chai et al., 2018; Tondeur et al., 2017). These studies revealed similar findings that teachers' general TPACK is correlated to their pedagogical beliefs. Recently, researchers have started to investigate teachers' pedagogy-specific TPACK, such as TPACK for game-based learning (TPACK-G) (Hsu et al., 2017), Constructivist-oriented TPACK (Koh et al., 2014), and TPACK for meaningful learning with ICT (Chai et al., 2011). However, there is a lack of relevant research exploring the relationship between teachers' specific TPACK for VFL and pedagogical beliefs.

In sum, teachers' technological pedagogical content knowledge (TPACK) for video-based flipped learning is still under-explored. Also, the relationship between teachers' specific TPACK for VFL and pedagogical beliefs is still not available. To fill the research gap, the current study aimed to develop a TPACK-VFL questionnaire for assessing teachers' TPACK for VFL and investigate a group of secondary school teachers' TPACK for VFL, their pedagogical beliefs, and the relationship between secondary school teachers' specific TPACK for VFL and pedagogical beliefs, as well as the role of teachers' pedagogical beliefs on their TPACK for VFL, was explored. The research questions in this study are: What are secondary school teachers' TPACK for VFL and their pedagogical beliefs?

1. Do junior high and senior high school teachers differ significantly in their TPACK for VFL?
2. Do secondary school teachers' TPACK for VFL significantly correlate to their pedagogical beliefs?

3. What is the role of secondary school teachers' pedagogical belief in their TPACK for VFL?

## 2 Research Method

### 2.1 Participants

In the education system in Taiwan, high schools, including junior high (Grade 7 ~ 9) and senior high schools (Grade 10 ~ 12), is the so-called secondary education. The participants in this study included both junior high school and senior high school teachers in Taiwan. There are two rounds of data collection in this study. The data collected in the first round was used to validate the TPACK-VFL Questionnaires for assessing secondary school teachers' TPACK for VFL (with exploratory factor analysis) and the Teacher Pedagogical Belief (TBQ) Questionnaire (with confirmatory factor analysis). Also, the data collected in the first round was used in the statistical analyses for answering this study's research questions. This study added a second round of data collection after receiving the reviewers' review comments regarding instrument validation for the TPACK-VFL Questionnaires. The data collected in this round was used to conduct confirmatory factor analysis (CFA) for validating the TPACK-VFL Questionnaire.

There were two groups of participants in this study. In the first round of data collection, the participants were 211 in-service secondary school teachers in Taiwan (81 males and 130 females). The mean age of the participant teachers was between 31 to 35. They were junior or senior high school teachers (including 145 junior high school teachers and 66 senior high school teachers). The participant teachers were from various subject domains (Chinese, English, Mathematics, Physics, Chemistry, Biology, History, Geography, Information, Music, Physical Education). They volunteered to attend a 2-day VFL workshop in a university in central Taiwan. In this workshop, some lectures related to VFL course design were delivered first, and then the participant teachers were divided into small groups, and each group was required to finish a VFL lesson plan. After the training in the workshop, all teachers were able to create instructional video clips and associated quizzes and uploaded the materials as part of the outcome. At the end of the workshop, all the 260 participant teachers were invited to be involved in this study, and 211 (about 81%) of the teachers were enrolled.

In the second round of data collection, the participants were 250 secondary school teachers in Taiwan (128 males and 132 females), including 195 junior high school and 55 senior high school teachers. Due to the COVID-19 pandemic, the data collection in this round was conducted with an online survey. All the participant teachers participated in this study voluntarily.

### 2.2 Video-based Flipping Learning in secondary schools

The typical VFL in the secondary schools in Taiwan is in line with the popular form of flipped learning and consists of two major parts: (1) out-of-class online learning and (2) in-class interactive learning. The purpose of out-of-class online learning activities is to prepare students for in-class learning instead of posing workload. Students are required to watch short instructional videos prior to class. After watching instructional videos, students are asked to finish online follow-up exercises and write down their questions. By doing so, teachers can identify students' learning weaknesses and problems and design appropriate in-class learning activities, such as discussion or inquiry activities. Thus, students can participate in in-class activities effortlessly. In-class learning activities are also fundamentally critical to the success of the VFL. At the beginning of a class, secondary teachers in Taiwan often briefly review the pre-class instructional videos and guide students in their group discussion with questions designed according to students' learning weaknesses and questions in their out-of-class online learning. In Taiwan, instructional videos for secondary learning are highly available for secondary teachers. Since most secondary teachers in Taiwan rely heavily on textbooks, the textbook publishers accordingly make videos. In addition, there are several free and open-source online learning platforms, such as Junyi Academy (a Chinese version of Khan Academy) and MOOCs developed by the Ministry of Education in Taiwan for primary and secondary learning. Using the videos obtained from the resources mentioned above, the secondary teachers in Taiwan can choose the instructional videos related to their courses for further editing, adding Chinese subtitles, or choosing the clips they want to use in their courses.

### 2.3 Instruments

To assess secondary teachers' TPACK for VFL and pedagogical beliefs, two questionnaires were used in this study. Based on the literature review on TPACK and VFL, and the authors experiences of creating Flipped lesson, knowledge (e.g., knowledge of self-directed learning) and skills (e.g., technological skills) necessary for teachers to create successful Flipped lesson were identified (see below). They were used to develop the TPACK-VFL Questionnaire in this study for assessing secondary school teachers' TPACK for VFL. Adapted from Chai et al. (2009), the Teacher Pedagogical Belief (TPB) questionnaire was used to evaluate the participant teachers' pedagogical beliefs. Both the two questionnaires were Likert-type rating scales presented with a bipolar scale ranging from strongly disagree/ strongly agree statements (i.e., strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, and strongly agree). For the items of the two instruments, please refer to the appendix.

The TPACK-VFL Questionnaire developed in this study included all seven types of teacher TPACK factors revealed in previous research, and it had a total of 41 items. The seven factors of the TPACK-VFL Questionnaire reflect the different kinds of knowledge that teachers need when they design and implement VFL. For example, concerning creating and streaming online videos, all TK items (9 items) reflect teachers' various skills. Since self-direction is necessary for students to preview the online instructional videos and collaborative learning is essential for in-class constructivist learning, the PK factors (5 items) reflect more specific knowledge about self-directed learning and collaborative learning. While there is no change in the CK and TCK factors (4 items and 3 items respectively) (Chai et al., 2011), the PCK factor (8 items) reflects in-class facilitation without technology. Less of the content knowledge presented, the TPK (8 items), which is necessary for teachers to master for TPACK-VFL, emphasizes the need for teachers to create pre-class activities that ensure and monitor students' pre-class learning with the implementation of video-based resources. Finally, the TPACK factor (4 items) reflects in-class constructivist-oriented computer-based learning.

The Teacher Pedagogical Belief (TPB) questionnaire in this study included two scales: learner-centered belief and teacher-centered belief.

1. *Learner-centered Pedagogy Scale* (4 items): measuring the extent to which the teacher will facilitate students' effort in making sense of the subject matter. A sample item is "A good class should help students think actively to construct knowledge.".
2. *Teacher-centered Pedagogy scale* (4 items): measuring the extent to which the teacher will transform subject matter knowledge and learning into the acquisition and accumulation of knowledge delivery. A sample item is "Teachers should have full control of students' learning.".

To ensure face validity, all the items in the TPACK-VFL and TPB questionnaires were carefully examined and reviewed by three TPACK researchers and subsequently by three in-service secondary school teachers.

### 2.4 Instrument Validation

To validate the TPACK-VFL Questionnaire, both exploratory factor analysis (EFA) and confirmtory factor analysis (CFA) were conducted sequently in this study. When performing the EFA, the extraction method was the Unweighted Least-Squares Method (ULS), and the rotation method was the Direct Oblimin Method with Kaiser normalization. The EFA results showed that the teachers' responses on the items of the TPACK-VFL Questionnaire were grouped into seven factors as the pre-defined structure for all the seven TPACK-VFL factors, and it explained a total variance of 74.42%. All the 41 items in the questionnaire were retained, and the factor loading of each item was larger than 0.50 as recommended by Fish and Dane (2000) (See Table 1). Moreover, the reliability (alpha) coefficients for seven factors of the TPACK-VFL Questionnaire were 0.91, 0.90, 0.96, 0.96, 0.96, 0.87, and 0.96 respectively, and the overall alpha was 0.97, indicating that the internal reliability of the TPACK-VFL Questionnaire is high (see Table 1).

Then, the factor structure of the TPACK-VFL Questionnaire that was obtained from the EFA was further validated through confirmatory factor analysis (CFA). The

**Table 1** EFA and reliability analysis results for the TPACK-VFL Questionnaire (N = 211)

| Item | Factor 1: *Content Knowledge* | Factor 2: *Pedagogical Knowledge* | Factor 3: *Pedagogical Content Knowledge* | Factor 4: *Technological Knowledge* | Factor 5: *Technology Pedagogical Knowledge* | Factor 6: *Technological Content Knowledge* | Factor 7: *Technological Pedagogical Content Knowledge* |
|---|---|---|---|---|---|---|---|
| *Factor 1*: *Content Knowledge* (CK) α = 0.91 | | | | | | | |
| CK1 | 0.84 | | | | | | |
| CK2 | 0.83 | | | | | | |
| CK3 | 0.78 | | | | | | |
| CK4 | 0.77 | | | | | | |
| *Factor 2*: *Pedagogical Knowledge* (PK) α = 0.90 | | | | | | | |
| PK1 | | 0.71 | | | | | |
| PK2 | | 0.70 | | | | | |
| PK3 | | 0.68 | | | | | |
| PK4 | | 0.55 | | | | | |
| PK5 | | 0.54 | | | | | |
| *Factor 3*: *Pedagogical Content Knowledge* (PCK) α = 0.96 | | | | | | | |
| PCK1 | | | 0.93 | | | | |
| PCK2 | | | 0.90 | | | | |
| PCK3 | | | 0.86 | | | | |
| PCK4 | | | 0.84 | | | | |
| PCK5 | | | 0.82 | | | | |
| PCK6 | | | 0.74 | | | | |
| PCK7 | | | 0.69 | | | | |
| PCK8 | | | 0.69 | | | | |
| *Factor 4*: *Technological Knowledge* (TK) α = 0.96 | | | | | | | |
| TK 1 | | | | 0.93 | | | |
| TK 2 | | | | 0.88 | | | |
| TK 3 | | | | 0.82 | | | |

**Table 1** (continued)

| Item | Factor 1: *Content Knowledge* | Factor 2: *Pedagogical Knowledge* | Factor 3: *Pedagogical Content Knowledge* | Factor 4: *Technological Knowledge* | Factor 5: *Technology Pedagogical Knowledge* | Factor 6: *Technological Content Knowledge* | Factor 7: *Technological Pedagogical Content Knowledge* |
|---|---|---|---|---|---|---|---|
| TK 4 | | | | 0.80 | | | |
| TK 5 | | | | 0.79 | | | |
| TK 6 | | | | 0.77 | | | |
| TK 7 | | | | 0.76 | | | |
| TK 8 | | | | 0.74 | | | |
| TK 9 | | | | 0.68 | | | |
| *Factor 5: Technology Pedagogical Knowledge* (TPK) α = 0.96 | | | | | | | |
| TPK 1 | | | | | 0.88 | | |
| TPK 2 | | | | | 0.80 | | |
| TPK 3 | | | | | 0.70 | | |
| TPK 4 | | | | | 0.70 | | |
| TPK 5 | | | | | 0.66 | | |
| TPK 6 | | | | | 0.66 | | |
| TPK 7 | | | | | 0.61 | | |
| TPK 8 | | | | | 0.51 | | |
| *Factor 6: Technological Content Knowledge* (TCK) α = 0.87 | | | | | | | |
| TCK 1 | | | | | | 0.65 | |
| TCK 2 | | | | | | 0.64 | |
| TCK 3 | | | | | | 0.59 | |
| *Factor 7: Technological Pedagogical Content Knowledge* (TPACK) α = 0.96 | | | | | | | |
| TPACK 1 | | | | | | | 0.91 |
| TPACK 2 | | | | | | | 0.90 |
| TPACK 3 | | | | | | | 0.78 |

**Table 1** (continued)

| Item | Factor 1: *Content Knowledge* | Factor 2: *Pedagogical Knowledge* | Factor 3: *Pedagogical Content Knowledge* | Factor 4: *Technological Knowledge* | Factor 5: *Technology Pedagogical Knowledge* | Factor 6: *Technological Content Knowledge* | Factor 7: *Technological Pedagogical Content Knowledge* |
|---|---|---|---|---|---|---|---|
| TPACK 4 | | | | | | | 0.73 |
| Eigenvalue | 2.30 | 5.47 | 1.01 | 3.00 | 17.87 | 1.16 | 1.47 |
| % of variance | 5.04 | 12.67 | 1.75 | 6.75 | 42.99 | 2.25 | 2.97 |

Notes: overall $\alpha = 0.97$, total variance explained is 74.42%

**Table 2** CFA results for the TPACK-VFL Questionnaire (n = 250)

| Factors | Items | Factor Loadings | Mean | SD | α | AVE | CR |
|---|---|---|---|---|---|---|---|
| Content Knowledge (CK) | CK4 | 0.80 | 3.75 | 0.74 | 0.90 | 0.70 | 0.90 |
| | CK3 | 0.86 | | | | | |
| | CK2 | 0.87 | | | | | |
| | CK1 | 0.81 | | | | | |
| Technological Content Knowledge (TCK) | TCK1 | 0.91 | 5.23 | 1.27 | 0.91 | 0.78 | 0.92 |
| | TCK2 | 0.87 | | | | | |
| | TCK3 | 0.88 | | | | | |
| Pedagogical Knowledge (PK) | PK1 | 0.78 | 5.49 | 0.81 | 0.89 | 0.63 | 0.89 |
| | PK2 | 0.83 | | | | | |
| | PK3 | 0.81 | | | | | |
| | PK4 | 0.80 | | | | | |
| | PK5 | 0.72 | | | | | |
| Technological Pedagogical Knowledge (TPK) | TPK1 | 0.71 | 4.79 | 1.29 | 0.96 | 0.74 | 0.96 |
| | TPK2 | 0.72 | | | | | |
| | TPK3 | 0.83 | | | | | |
| | TPK4 | 0.84 | | | | | |
| | TPK5 | 0.88 | | | | | |
| | TPK6 | 0.91 | | | | | |
| | TPK7 | 0.93 | | | | | |
| | TPK8 | 0.94 | | | | | |
| Technological Knowledge (TK) | TK1 | 0.85 | 5.07 | 1.54 | 0.95 | 0.69 | 0.95 |
| | TK2 | 0.92 | | | | | |
| | TK3 | 0.89 | | | | | |
| | TK4 | 0.84 | | | | | |
| | TK5 | 0.81 | | | | | |
| | TK6 | 0.78 | | | | | |
| | TK7 | 0.79 | | | | | |
| | TK8 | 0.71 | | | | | |
| | TK9 | 0.86 | | | | | |
| Pedagogical Content Knowledge (PCK) | PCK1 | 0.77 | 5.46 | 0.84 | 0.94 | 0.66 | 0.94 |
| | PCK2 | 0.83 | | | | | |
| | PCK3 | 0.87 | | | | | |
| | PCK4 | 0.86 | | | | | |
| | PCK5 | 0.78 | | | | | |
| | PCK6 | 0.80 | | | | | |
| | PCK7 | 0.79 | | | | | |
| | PCK8 | 0.79 | | | | | |
| Technological Pedagogical Content Knowledge (TPCK) | TPCK1 | 0.81 | 4.38 | 1.47 | 0.94 | 0.79 | 0.94 |
| | TPCK2 | 0.88 | | | | | |
| | TPCK3 | 0.96 | | | | | |
| | TPCK4 | 0.92 | | | | | |

CFA results are presented in Table 2, which reported the factor loadings, the mean and standard deviation values, the average variance extracted (AVE), composite reliability (CR), and Cronbach's alpha values. The findings indicate that the measurement model satisfied the criteria stated by Hair et al. (2010) (chi-square = 1594.33, $p < 0.001$, degree of freedom = 750, $\chi 2$ per degree of freedom = 2.13, CFI = 0.92, TLI = 0.91, RMSEA = 0.067). The overall reliability of the survey is 0.97. As indicated in Table 2, the CR values exceeded 0.70 (0.89—0.96), the AVE values exceeded 0.50 (0.63—0.79), and the Cronbach's alpha values exceeded 0.70 (0.89—0.96). The above information revealed that the construct validity of the questionnaires could be accepted (Fornell & Larcker, 1981).

Table 3 presents the Pearson correlations and the square root of the AVE in parenthesis of each factor. With reference to Fornell and Larcker's (1981), the square root of the AVE values should be higher than 0.5 and larger than the correlation coefficients between the factors. As shown in the Table, the conditions have been satisfied and hence the convergent and discriminant validity of TPACK-Flipped model is acceptable (Hair et al., 2010). The results derived from Tables 2 and 3 further confirmed the validity of the factor structure obtained in the EFA.

Moreover, another CFA was conducted to confirm the structure of the Teacher Pedagogical Belief (TPB) Questionnaire. The fit indices show good fit of the 2 factor model (chi-square = 43.88, $p < 0.001$, degree of freedom = 19, $\chi 2$ per degree of freedom = 2.31, CFI = 0.98, TLI = 0.97, RMSEA = 0.079) (Hair et al., 2010). The factors loading ranges from 0.90—0.94 for the Learner-centered Pedagogy Scale and 0.73–0.80 for the Student-centered Pedagogy Scale. The results confirmed the validity of the factor structure of the TPB Questionnaire.

# 3 Results and Discussion

## 3.1 Teachers' TPACK for VFL and Pedagogical Belief (Research Question 1)

Table 4 shows teachers' average item scores and standard deviations on the TPACK-VFL Questionnaire and TPB Questionnaire scales. According to Table 4, among the seven scales of the TPACK-VFL Questionnaire, the teachers scored higher on

**Table 3** The correlation matrix and discriminant indexes for the TPACK-VFL Questionnaire ($n = 250$)

| | CK | PK | PCK | TK | TPK | TCK | TPCK |
|---|---|---|---|---|---|---|---|
| CK | (0.837) | | | | | | |
| PK | 0.633** | (0.793) | | | | | |
| PCK | 0.615** | 0.787** | (0.812) | | | | |
| TK | 0.294** | 0.355** | 0.330** | (0.831) | | | |
| TPK | 0.363** | 0.529** | 0.535** | 0.658** | (0.860) | | |
| TCK | 0.351** | 0.447** | 0.459** | 0.640** | 0.687** | (0.883) | |
| TPCK | 0.273** | 0.450** | 0.444** | 0.564** | 0.728** | 0.688** | (0.889) |

**. Correlation is significant at the 0.01 level (2-tailed).

**Table 4** Teachers' scores on the TPACK-VFL and TPB Questionnaires (N = 211)

| TPACK-VFL Questionnaire | # of items | Item mean | S.D |
|---|---|---|---|
| Content Knowledge | 4 | 5.93 | 0.71 |
| Pedagogical Knowledge | 5 | 5.31 | 0.96 |
| Technological Knowledge | 9 | 4.70 | 1.42 |
| Pedagogical Content Knowledge | 8 | 4.92 | 1.52 |
| Technology Pedagogical Knowledge | 8 | 5.26 | 0.96 |
| Technological Content Knowledge | 3 | 4.31 | 1.37 |
| Technological Pedagogical Content Knowledge (TPACK) | 4 | 4.13 | 1.50 |
| TPB Questionnaire | # of items | Item mean | S.D |
| Learner-centered Pedagogy | 4 | 6.10 | 0.86 |
| Teacher-centered Pedagogy | 4 | 4.04 | 1.38 |

the "Content Knowledge" (an average of 5.93 per item), followed by "Pedagogical Knowledge" (an average of 5.31 per item), "Technological Pedagogical Knowledge" (an average of 5.26 per item), "Pedagogical Content Knowledge" (an average of 4.92 per item), "Technological Knowledge" (an average of 4.70 per item), "Technological Content Knowledge" (an average of 4.31 per item), and "Technological Pedagogical Content Knowledge" (an average of 4.13 per item). The results indicated that the participant teachers in this study, on average, had relatively better confidence in their content knowledge (CK), pedagogical knowledge (PK), and technological pedagogical knowledge (TPK) for VFL. In comparison, they had less confidence in their technological knowledge (TK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPACK) for VFL. Content knowledge (CK), pedagogical knowledge (PK), and technology knowledge (TK) are the three fundamental forms of knowledge in the TPACK framework proposed by Mishra and Koehler (2006).

Table 4 also reveals that compared with content knowledge (CK) and pedagogical knowledge (PK), two crucial components in Shulman's PCK (1986) framework), the participant teachers expressed only slightly positive confidence in technological knowledge (TK) for VFL. Previous research indicated that if the instructional videos for VFL could be obtained easily, most teachers tend to use them directly rather than produce instructional videos by themselves (Gulbahar & Guven, 2008; Neaupane, 2017; Wang, 2011). As aforementioned, textbooks publishers make videos for teachers in Taiwan, and instructional videos can be obtained easily from free and open-source online learning platforms. Thus, secondary teachers in Taiwan tend to use instructional videos that are already available directly. In other words, the secondary teachers in this study may not have sufficient experience in further video editing, adding Chinese subtitles, or cutting the clips from the videos they want to use in their courses. As a result, they may be less confident in technological knowledge (TK) for VFL. Therefore, it suggests that teacher professional development or training programs targeted at helping teachers enhance their technology-related knowledge and subsequently drawing upon it to create VFL are necessary. In particular, these teacher professional development or training programs should develop teachers' basic knowledge and ability to handle and work on computer software and hardware to produce short instructional videos by themselves.

Moreover, Graham (2011) and Lin et al. (2013) have advocated that teachers' technological content knowledge (TCK) is an area that needs attention. Similarly, the teachers in this study expressed relatively lower confidence in their technological content knowledge (TCK) (mean = 4.31). The finding suggests that teacher educators need to model how TCK can be tapped upon a VFL pedagogy. It should also be noticed that the secondary school teachers showed the lowerest confidence in technological pedagogical content knowledge (TPACK). It may result from their insufficient TK and TCK.

Regarding the teachers' pedagogical belief, Table 4 revealed that the participants appeared to have a stronger learner-centered pedagogical belief (an average of 6.10 per item) and moderate teacher-centered pedagogical belief (an average of 4.04 per item). Again, the trend is similar to the profile of teachers' beliefs reported using similar measures (see Chai et al., 2009).

### 3.2 Differences Between Junior and Senior High teachers' TPACK for VFL (Research Question 2)

With a series of independent sample t-tests, Table 5 shows that the junior high school teachers and the senior high school teachers only had significant differences in terms of their scores on the "Technological Pedagogical Content Knowledge" scale ($p < 0.01$), indicating that, compared with the senior high school

**Table 5** Summary of independent sample t-test results regarding the difference in teachers' TPACK for VFL and pedagogical belief by the two different teacher groups

| Scale | Groups | Mean | S.D | t |
|---|---|---|---|---|
| Content Knowledge | Junior high school teacher (n = 145) | 5.88 | 0.73 | -1.56 |
| | Senior high school teacher (n = 66) | 6.03 | 0.65 | |
| Pedagogical Knowledge | Junior high school teacher (n = 145) | 5.29 | 1.01 | -0.48 |
| | Senior high school teacher (n = 66) | 5.35 | 0.86 | |
| Pedagogical Content Knowledge | Junior high school teacher (n = 145) | 5.25 | 1.01 | -1.73 |
| | Senior high school teacher (n = 66) | 5.27 | 0.82 | |
| Technological Knowledge | Junior high school teacher (n = 145) | 5.05 | 1.40 | 1.61 |
| | Senior high school teacher (n = 66) | 4.65 | 1.73 | |
| Technology Pedagogical Knowledge | Junior high school teacher (n = 145) | 4.38 | 1.39 | 1.26 |
| | Senior high school teacher (n = 66) | 4.13 | 1.33 | |
| Technological Content Knowledge | Junior high school teacher (n = 145) | 4.82 | 1.34 | 1.80 |
| | Senior high school teacher (n = 66) | 4.43 | 1.55 | |
| Technological Pedagogical Content Knowledge | Junior high school teacher (n = 145) | 4.29 | 1.50 | 2.27* |
| | Senior high school teacher (n = 66) | 3.39 | 1.46 | |

* $p < 0.05$.

teachers, the junior high school teachers showed higher confidence in VFL implementation (i.e., TPACK). However, it should be noticed that the junior high school teachers had moderate confidence in their TPACK for VFL, while the senior high school teachers were below the mean of 4 for their TPACK for VFL. It may be attributed to the fact that the senior high school teachers are more occupied with preparing students for exams than the junior high school teachers; thus, they may have few opportunities to understand, experience, and practice VFL.

### 3.3 Correlation Between Teachers' TPACK for VFL and Pedagogical Belief (Research Question 3)

In previous research, TPACK researchers have concerned themselves with the relationship between TPACK and teachers' pedagogical beliefs. According to the results in Table 6, the teachers' learner-centered pedagogical belief was significantly correlated with their CK, PK, PCK, TCK, and TPK ($p < 0.05$), while their teacher-centered pedagogical belief was significantly associated with their TCK TPK and TPACK ($p < 0.05$).

It should be particularly noticed that those teachers who held stronger teacher-centered pedagogical belief showed higher self-efficacy of implementing VFL (i.e., they had better perceived TPACK). However, in Chai et al. (2013), it was revealed that teachers' constructivist-oriented pedagogical belief (i.e., learner-centered pedagogical belief in this study) was significantly associated with all TPACK factors while the traditional belief (i.e., teacher-centered pedagogical belief in this study) was only associated weakly with TCK. Thus, the results derived from this study are somewhat different from those revealed in the Chai et al. (2013). It seems that VFL is quite different from conventional ICT integration pedagogy. When implementing VFL, on the one hand, students' watching video-based lectures before class is quite similar to the conventional deductive approach, which is regarded as a teacher-centered pedagogy; on the other hand, in class, students typically have the opportunities to engage in learner-centered learning activities, such as problem-based or group-based in-depth discussions. That is, teachers' TPACK for VFL is different from conventional and general TPACK for ICT integration. To develop teachers' TPACK for VFL, both teacher-centered pedagogical belief and learner-centered belief play crucial roles.

**Table 6** The correlation between teachers' TPACK for VFL and their pedagogical beliefs

| | CK | PK | TK | PCK | TCK | TPK | TPACK |
|---|---|---|---|---|---|---|---|
| Learner-centered pedagogy | 0.38** | 0.41** | 0.08 | 0.31** | 0.18** | 0.15* | 0.01 |
| Teacher-centered pedagogy | 0.74 | 0.87 | 0.09 | 0.11 | 0.14* | 0.20** | 0.34** |

* $p < .05$; ** $p < .01$

### 3.4 The role of teachers' pedagogical belief in teachers' TPACK for VFL (Research Question 4)

In previous, the relationship between teachers' perceptions of classroom authority (or their epistemic beliefs) and their TPACK was further explored using cluster analysis and ANOVA tests (Liang, 2015; Xi et al., 2020). In these studies, cluster analyses were conducted to identify the diverse types of teachers' perceptions of classroom authority or epistemic beliefs based on their responses to the factors of a questionnaire or survey. Similar to the previous studies (e.g., Xi et al., 2020), the current study also applied a two-step clustering approach to ensure the accuracy of the identified teacher clusters. In this study, both the mean scores of the two scales of the TPB Questionnaire were used as the cluster variables in the Two-Step cluster analysis. A Hierarchical Cluster Analysis with the Ward's minimum variance method was conducted to determine the appropriate number of teacher clusters. Then, based on the number of teacher clusters identified, the K-means cluster method was then used to identify the features of each teacher cluster. Finally, a series of ANOVA tests were conducted to examine the differences on the teachers' perceived TPACK for VFL among the different teacher clusters.

The cluster analysis in this study revealed a three-cluster solution, as shown in Fig. 1. For the validation of the cluster analysis, the silhouette measure of cohesion and separation is larger than 0.5, indicating good internal cluster validity. Based on the two cluster variables from which they were characterized, the three clusters were named as follows.

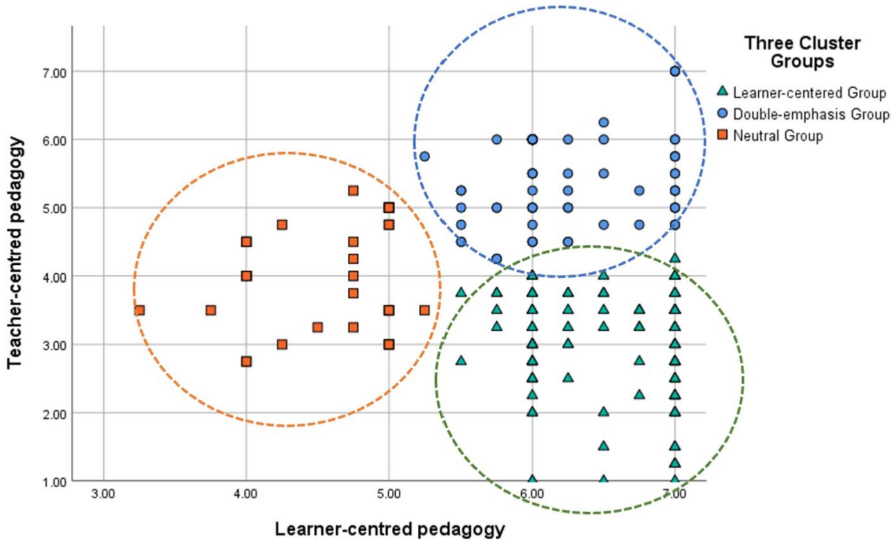


**Fig. 1** The three pegagogical belief groups derived from the cluster analysis

1. The *Learner-centered Group* was the largest group (n = 99), with 46.9% of the participant teachers in this study. The teachers in this group had strong learner-centered pedagogical belief (Mean = 6.52) and weak teacher-centered pedagogical belief (Mean = 2.94).
2. The *Double-emphasis Group* (n = 77) consisted of 36.5% of the secondary teachers in this study. The teacheres in this group held both strong learner-centered and teacher-centered pedagogical beliefs (Mean = 6.27 and 5.47 respectively).
3. The *Neutral Group* (n = 35) comprised 16.6% of the secondary teachers in this study. The teacheres in the Neutral Group held moderate learner-centered and teacher-centered pedagogical beliefs (Mean = 4.54 and 3.99 respectively).

One-way ANOVA was also conducted to further examine the difference among the three teacher groups. As revealed in Table 7, the three clusters of teachers differed significantly in their learner-centered pedagogical belief ($F = 209.9$, $p < 0.001$) and teacher-centered pedagogical belief ($F = 240.9$, $p < 0.001$). A series of Scheffe tests (post hoc tests) further indicated that the teachers in the Learner-centered Group had significantly stronger learner-centered pedagogical beliefs and significantly weaker teacher-centered pedagogical beliefs than both the teachers in the Double-emphasis Group and the Neutral Group ($p < 0.05$). Besides, the students in the Double-emphasis Group held both significantly stronger learner-centered and teacher-centered pedagogical beliefs than those in the Neutral Group ($p < 0.05$). The results above revealed that the three groups of teachers did hold various pedagogical beliefs, indicating the good cluster quality for cluster analysis.

Moreover, this study further examined the role of teachers' pedagogical belief in their TPACK for VFL. As shown in Table 8, the results derived from the ANOVA showed that the teachers' pedagogical beliefs played a role in their CK, PK, PCK, and TPACK. A series of Scheffe tests (post hoc tests) further revealed that the teachers in the Learner-centered Group only significantly outperformed those in the Neutral Group ($p < 0.05$) in CK. However, the teachers in the Double-emphasis Group expressed significantly higher self-efficacy than those in the Neutral Group in terms of CK, PK, and PCK; also, they outperformed those in the Learner-centered Group in TPACK. It seemed that, in general, the teachers in the Double-emphasis Group

**Table 7** ANOVA results regarding the difference in pedagogical beliefs among the three teacher groups (N = 211)

| | Learner-centered pedagogical belief (mean, S.D.) | Teacher-centered pedagogical belief (mean, S.D.) |
|---|---|---|
| 1: Learner-centered group (n = 99) | (6.51, 0.48) | (2.93, 0.81) |
| 2 Double-emphasis Group (n = 77) | (6.27, 0.52) | (5.47, 0.70) |
| 3 Neutral Group (n = 35) | (4.53, 0.51) | (3.99, 0.75) |
| F(ANOVA) | 209.9*** | 240.9**** |
| Scheffe Test | 1 > 2 > 3 | 2 > 3 > 1 |

** $p < .01$; *** $p < .001$

**Table 8** An analysis of the role of teachers' pedagogical belief in their TPACK for VFL (N = 211)

| | CK (mean, S.D.) | PK (mean, S.D.) | PCK (mean, S.D.) | TK (mean, S.D.) | TPK (mean, S.D.) | TCK (mean, S.D.) | TPACK (mean, S.D.) |
|---|---|---|---|---|---|---|---|
| 1 Learner-centered (n = 99) | (5.98, 0.64) | (5.33, 0.94) | (5.25, 0.92) | (4.96, 1.60) | (4.18, 1.47) | (4.67, 1.49) | (3.74, 1.56) |
| 2 Double-emphasis (n = 77) | (6.05, 0.61) | (5.48, 0.96) | (5.46, 0.97) | (5.00, 1.50) | (4.57, 1.34) | (4.93, 1.31) | (4.58, 1.50) |
| 3 Neutral (n = 35) | (5.51, 0.90) | (4.88, 0.94) | (4.84, 0.89) | (4.65, 1.31) | (4.06, 1.08) | (4.28, 1.38) | (4.23, 0.95) |
| F(ANOVA) | 8.10*** | 4.93** | 5.19** | 0.69 | 2.41 | 2.64 | 7.34** |
| Scheffe Test | 1 > 3; 2 > 3 | 2 > 3 | 2 > 3 | | | | 2 > 1 |

** $p < .01$; *** $p < .001$

showed better TPACK for VFL. That is, those teachers who held both strong learner-centered and teacher-centered pedagogical beliefs might be more confident of implementing VFL. The findings above confirm that TPACK researchers' concerns about teachers' beliefs are well warranted (e.g., Tondeur et al., 2017). Moreover, it also suggests that both teacher-centered and learner-centered beliefs play crucial roles in secondary school teachers' implementation of VFL.

### 3.5 Conclusion and implication

In recent years, VFL has become a common and popular form of flipped learning. However, only a few studies have addressed the role of teachers on VFL in the contexts of secondary education. In particular, teachers' technological pedagogical content knowledge (TPACK) for VFL is still under-explored. In order to fill up this research gap, this study developed and validated a TPACK-VFL Questionnaire for assessing teachers' TPACK for VFL. With TPACK-VFL Questionnaire, this study investigated secondary school school teachers' TPACK for VFL. This study revealed that the participant teachers, in general, showed slightly positive confidence in their TPACK for VFL. More specifically, these teachers, on average, had relatively better confidence in their content knowledge (CK), pedagogical knowledge (PK), and technological pedagogical knowledge (TPK) for VFL; In comparison, they had less confidence in their technological knowledge (TK), technological content knowledge (TCK), and technological pedagogical content knowledge (TPACK) for VFL. The results point to the need for professional development activities to primarily address the technology-related component of TPACK for VFL. Besides, this study found that, compared with the senior high school teachers, the junior high school teachers in this study showed higher confidence in TPACK for VFL. More importantly, this study revealed that those teachers who held both strong learner-centered and teacher-centered pedagogical beliefs might be more confident of practicing VFL (i.e., have better self-perceived TPACK).

This study is one of the initial attempts to explore secondary teachers' TPACK for VFL, and the findings in this study may be helpful for educators to get some insights into secondary teachers' TPACK for VFL. This study also has several significant implications for future research and teacher education. With a quantitative method, this study explored secondary teachers' TPACK for VFL. Future research with a qualitative research method or a mixed research method is suggested to confirm the initial findings regarding teachers' TPACK for VFL in this study. Also, for future research, to obtain the whole picture and know teachers' TPACK thoroughly, a combination of different data collecting methods, such as classroom observation, students' self-reflections, and qualitative interviewing, are suggested to be used to explore teachers' TPACK for VFL. Moreover, follow-up research could be conducted to investigate the effects of teachers' belief on teachers' TPACK for VFL, instructional design for VFL, teaching practice regarding VFL, and students' learning performance in VFL.

The findings of this study could serve as crucial elements for teacher educators for designing and implementing teacher education and professional development programs to raise teachers' perceived levels of TPACK for VFL. Through the questionnaire investigation, this study revealed that teachers showed slightly positive confidence in their TPACK for VFL for teacher education. The results suggest that more professional development programs may be needed in teacher education and training. However, these programs are still rarely available. Therefore, the design of teacher education regarding the teachers' TPACK for VFL and the assessment of their TPACK for VFL can be a crucial issue for teacher educators.

## Appendix

**Items of TPACK-VFL Questionnaire.**

**Content Knowledge (CK).**

CK1 I have sufficient professional knowledge on the subject content knowledge that I teach.

CK2 I have sufficient confidence to teach the subject content knowledge that I teach.

CK3 I can develop a deeper understanding of the content knowledge I teach.

CK4 I can think of content knowledge experts on the subject content knowledge that I teach.

**Pedagogical Knowledge (PK).**

PK1 I can guide my students to adopt suitable learning strategies.

PK2 I can help my students broaden their thinking by designing challenging learning tasks.

PK3 I can help my students reflect on their learning strategies.

PK4 I can guide my students to have practical discussions.

PK5 I can help my students monitor their learning process.

**Pedagogical Content Knowledge (PCK).**

PCK1 After students finish their pre-class previewing, I can assist students in understanding the content knowledge by adopting various teaching methods in my class.

PCK2 After students finish their pre-class previewing, I can have effective teaching focusing on students' learning difficulties in the subject content knowledge in my class.

PCK3 After students finish their pre-class previewing, I can lead them to participate in meaningful discussions focusing on the subject content knowledge in my class.

PCK4 After students finish their pre-class previewing, I can evaluate students learning outcomes in my class.

PCK5 After students finish their pre-class previewing, I can provide authentic questions to help them think deeply about my class's subject content knowledge.

PCK6 After students finish their pre-class previewing, I can guide them to actively participate in activities in practice related to the subject content knowledge in my class.

PCK7 After students finish their pre-class previewing, I can help them manage their learning process on their subject content knowledge in my class.

PCK8 After students finish their pre-class previewing, I can teach students their common myths in the subject content knowledge in my class.

**Technological Knowledge (TK).**

TK1 I know how to add subtitles to videos.

TK2 I know how to edit two videos and combine them into one.

TK3 I know how to make videos using various technology products (e.g., tape recorders, small phones…)

TK4 I know how to convert video files into different formats (e.g., WMV to MPEG).

TK5 I know how to add voice to videos.

TK6 I know how to use video editing software to edit video files.

TK7 I know how to solve technical problems when I adopt audio and video technology.

TK8 I know how to increase videos' quality (e.g., turning up the volume or enlarging the picture pixels).

TK9 I know how to upload videos to online platforms.

**Technological Pedagogical Knowledge (TPK).**

TPK1 When students are doing pre-class video previewing; I make students discuss on online discussion platforms.

TPK2 When students do pre-class video previewing; I make students finish group discussion tasks on online discussion platforms.

TPK3 When students are doing pre-class video previewing; I can understand students' learning process through adequate online assessments.

TPK4 When students do pre-class video previewing; I will encourage students to finish lessons before class.

TPK5 When students do pre-class video previewing; I can understand students' learning outcomes through adequate online assessments.

TPK6 When students are doing pre-class video previewing, I will evaluate student's learning outcomes through online platforms (e.g., online testing systems)

TPK7 When students are doing pre-class video previewing; I can help students to construct various knowledge representations.

TPK8 When students are doing pre-class video previewing; I can guide students to authentic learning contexts.

**Technological Content Knowledge (TCK).**

TCK1 I know how to use adequate technology (e.g., multimedia resources, computer simulation) to represent content knowledge.

TCK2 I know some technologies that can help me research the subject I teach.

TCK3 I know how to conduct research using professional software relating to my subject domain.

**Technological Pedagogical Content Knowledge (TPACK).**

TPACK1 After students finish their pre-class previewing, I can help them construct various knowledge representations of different subject content by using adequate information technology tools (e.g., Webspiration, Midmeister, Wordle).

TPACK2 After students finish their pre-class previewing, I can help students find solutions to authentic problems related to subject content knowledge by guiding them to use information technology tools (e.g., simulations, web-based materials).

TPACK3 After students finish their pre-class previewing, I can guide them to explore the subject content knowledge using adequate information technology tools (e.g., simulations, web-based materials).

TPACK4 After students have finished their pre-class previewing, I can choose adequate technology (e.g., Google Sites, CoveritLive) on subjects for promoting students' group collaboration.

**Items of Teacher Pedagogical Belief (TPB) Questionnaire.**

**Learner-centered Pedagogy Scale.**

LC1 A good class should help students to think actively to construct knowledge.

LC2 Teachers should greatly encourage students to explore, discuss, and express their opinions.

LC3 Effective teaching should encourage students to have more discussions and practices.

LC4 Teaching should be of flexibility to serve the need of students' individual differences and learning process.

**Teacher-centered Pedagogy Scale**

TC1 Learning is mainly through repetitive practice and drills.

TC2 Teachers should have full control of students' learning.

TC3 The major job of teachers is to convey knowledge to students.

TC4 Authoritarian teaching is the best practice in class.

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## Declarations

**Conflict of Interest** None.

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