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RESEARCH ARTICLE

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Actualization of teaching conceptions in lesson design: how teaching conceptions shape TPACK regarding spherical video-based virtual reality-supported writing instruction

Mengyuan Chen[1,2] · Ching-sing Chai[3] · Morris Siu-Yung Jong[3]

Abstract

The effective application of spherical video-based virtual reality (SVVR) in writing education depends on teachers' lesson design, which is deeply influenced by their technological pedagogical and content knowledge (TPACK). However, how teaching conceptions, as the fundamental viewpoint that influences teachers' teaching focuses, shape their TPACK remains uncertain. This study aimed to explore how teachers' conceptions shape their TPACK regarding SVVR-supported writing instruction. Twenty-one secondary school teachers participated in this study and conducted one semester of SVVR-supported writing lessons. Data were collected through semi-structured interviews, and the interview transcriptions were analyzed using content analysis to explore the association between the teaching conceptions and TPACK. Teaching conceptions were classified into three orientations, namely skill, community, and identity, to reflect the teachers' teaching focuses. TPACK was classified into three categories, namely Replacement, Amplification, and Transformation, to indicate the levels of integrating SVVR into the writing lessons. The results showed that teachers with students' identity-focused conceptions shaped their TPACK at the Transformation level of SVVR integration. Teachers with community-focused conceptions developed students' emotional connections with people and places through their TPACK for deeper writing. Teachers with skill-focused conceptions, on the other hand, shaped their TPACK at the Replacement level that replaced the existing teaching activities and resources with SVVR to teach students writing skills. The findings suggest that teachers may need to shift the conceptions of writing instruction toward identity orientation to develop transformative TPACK.

Keywords Augmented and virtual reality · Improving classroom teaching · Pedagogical issues · Teaching/learning strategies · Secondary education

Introduction

Educators recognize that high-quality writing conveys affection that resonates with readers through vicarious experience, and such affection requires writers to feel the written world emotionally (Carter, 2015; MacArthur et al., 2008; Ridley et al., 2022). Cultivating

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Extended author information available on the last page of the article

such authentic writing ability requires a well-designed writing program that goes beyond transmitting linguistic knowledge pertaining to writing skills. Writing instruction may need to foster sociocultural connections as the foundation on which to cultivate writer identity among students (Chen et al., 2021a). However, teaching students to write with affection and original ideas to engage readers is difficult in teacher-centered and product-focused classrooms (Graham, 2018; Yang et al., 2021). Such pedagogical practices may not be preferred by students, as they fail to engage the students either cognitively or socially (Chai et al., 2019).

Underpinned by the embodied cognition theory and experiential learning (Nguyen et al., 2020), studies have increasingly focused on leveraging the potential of spherical video-based virtual reality (SVVR) technology in constructing immersive and authentic learning environments for writing (Chien et al., 2020; Huang et al., 2020). The images in SVVR environments are filmed in the real world, so users can observe vivid details of the virtual environments while wearing a simple headset (e.g., Google cardboard glasses) (Geng et al., 2021). Their low cost and easy operation make SVVR-supported writing programs more accessible in primary and secondary schools (Chien et al., 2020).

Research has shown that the overall effects of a strong SVVR-supported writing program help to reduce students' writing problems such as a lack of vivid description, inability to convey affection, and failure to depict nuanced understandings of a society (Li et al., 2020; DeWitt et al., 2022). Researchers have highlighted that the success of immersive SVVR-supported learning is dependent on transformative pedagogy to create an autonomous learning environment. Such transformation shifts the teacher-centered and product-focused pedagogy towards student-centered and process-focused pedagogy (Hughes et al., 2006). The shift is likely to be connected to the teachers' conceptions of teaching (Hsieh & Tsai, 2017).

Teaching conception is a framework that reveals how teachers think about the learning objectives, pedagogical affordances of technologies, the roles of teachers and students, and the learning process (Vermunt & Vermetten, 2004). Research has consistently shown that teaching conceptions that focus on student ownership stimulate transformative technology-assisted pedagogy design and practice (Kong, 2018; Wang & Matsumura, 2019). Researchers have also suggested that the effect of teachers' teaching conceptions on the enactment of classroom practices is most likely mediated by their knowledge of teaching (Yeh et al., 2021). The Technological Pedagogical and Content Knowledge (TPACK) framework is viewed as a dynamic knowledge framework in which teachers use their technological, pedagogical, and content knowledge to design and implement lessons, and foster students' thinking and learning with digital technologies in various subjects (Mishra et al., 2019). Teachers' TPACK is hence a highly contextualized form of constructed knowledge that varies from lesson to lesson, and is formulated by teachers considering their lesson objectives based on the topics, students' characteristics and school contexts. While a growing number of articles have focused on the effects of SVVR-supported writing instruction (for convenience, hereinafter referred to as VRWI) (e.g., Chen et al., 2021b; Chien et al., 2020; Yang et al., 2021), how teaching conceptions shape teachers' TPACK construction for VRWI remains uncertain. Unpacking the associations between these two constructs will provide important insights into how to effect deep changes and advance better design use of SVVR for writing instruction. Given the research gaps, this study aimed to explore the actualization of teachers' conceptions of VRWI from the perspective of TPACK. This study therefore proposed the following research questions:

Q1: How do the teachers conceive VRWI?

Q2: How do the teachers account for their TPACK construction when they design and implement the SVVR-based pedagogy for writing?

Q3: How is teachers' TPACK (i.e., SVVR-based pedagogy for writing) associated with their conceptions of VRWI?

Literature review

Teaching conceptions of SVVR-supported writing instruction

Conceptions are meaning-making frameworks that mediate the conceivers' responses to phenomena and situations (Pratt, 1992). In the context of technology-assisted instruction, teaching conceptions are teachers' comprehensive and fundamental views of technology use in teaching. Teaching conceptions embody teachers' pedagogical concerns and determine their pedagogical goals (Wang & Matsumura, 2019). They represent the perspectives through which teachers construct the technology-assisted classroom. Researchers usually illustrate conceptions of teaching through several hierarchical categories (Hsieh & Tsai, 2017; Vermunt & Vermetten, 2004). For example, Boulton-Lewis et al. (2001) described four categories of teaching conceptions. The first category, *transmission of content and skills*, perceives teaching as a means of imparting information or skills. The second category, *development of skills and understanding*, involves the teacher directing the learning process with students as participants. The third category, *facilitation of understanding*, focuses on both the teacher and students working together to construct personal meaning. The fourth category, *teaching transformation*, involves the teacher organizing learning environments for students to take action by extending themselves cognitively, behaviorally, and affectively. The categories of teaching conceptions held by teachers are the lenses through which the surrounding world is perceived and interpreted; teachers form conceptions and enact teaching practices according to them (Kong, 2018; Wang & Matsumura, 2019).

Previous research on conceptions regarding the use of SVVR to teach the first language composition established three orientations of conceptions as "skill-oriented," "community-oriented," and "identity-oriented" from phenomenographic analysis (Chen et al., 2021a). Studies indicated that teachers who held "skill-oriented" conceptions focused on writing skills, implicitly referencing performance that could be measured by examination. Regarding "community-oriented" conceptions, teachers include collaborative and autonomous learning as part of the writing process, which represents a richer conception of writing that goes beyond examination. The most sophisticated conception for the teaching of writing is focused on developing the identity of writers. This conception emphasizes the subjectivity of writing through personal meaning-making, and self-conscious choice from the diverse cultural resources at one's disposal, which build a unique writer identity.

Nevertheless, teaching conceptions, as a kind of ideological consciousness, need to be transformed into specific knowledgeable actions (Markauskaite & Goodyear, 2017) for classroom teaching. To cultivate teachers' computer-assisted teaching ability, researchers need to understand how teaching conceptions, which are adopted in this study to characterize teachers' teaching beliefs (Boschman et al., 2014), shape their understanding and use of technologies. Given this research need, this study aimed to unpack the associations of teaching conceptions and TPACK for VRWI.

The TPACK of technology-assisted language learning

Context has been recognized as an important variable that influences teachers' TPACK (Roussinos & Jimoyiannis, 2019; Swallow & Olofson, 2017). In essence, teachers' TPACK is constructed for specific students situated in a specific school context to help them attain the subject-based learning outcomes that the teachers deem appropriate (Mishra, 2019). Through analyzing the TPACK of language teachers, researchers have found that teachers demonstrate computer-assisted language teaching knowledge and abilities when selecting appropriate technologies for content teaching, choosing or making digital learning and teaching materials, using digital technologies for student interaction, and designing the use of matching technology to meet their teaching goals and pedagogies (Tai, 2015; Tseng et al., 2020). How teachers account for their construction of TPACK has been explored (Koh et al., 2014; McKenney & Voogt, 2017), but more research is needed given the variation in the choice of technologies, pedagogies, and topic-based subject matter, and the variation in contexts.

In addition, researchers have pointed out that the studies on language teachers' TPACK published in recent years showed that the technologies used by language teachers were designed primarily for traditional teacher-centered instruction (Tseng et al., 2020). Merely integrating technologies to enhance teacher-centered instruction and replacing the existing resources and activities may not optimize the use of technologies (Cheah et al., 2019). Instead, researchers should explore the TPACK of language teachers to support student-centered learning that could foster students' lifelong language learning abilities beyond school. In addition, compared with the research on foreign language teachers, relatively few TPACK studies have focused on the first language, and most existing studies did not specifically distinguish writing, reading, speaking, and listening (Cheng, 2017; Saudelli & Ciampa, 2016).

The level of technology integration in teaching

The use of technologies for education is often seen as a means of achieving specific teaching and curriculum purposes (Kimmons et al., 2015). A more in-depth study of the end-use of technologies, rather than simply focusing on the types and quantities of software programs used by teachers, will more accurately reflect the level of technology use (Hsieh & Tsai, 2017). A teacher's TPACK reflects the pedagogical purpose for using technologies, and researchers have found that these purposes can be classified into different levels, resulting in different teaching effects (Tai, 2015; Tseng et al., 2020).

To understand the level of SVVR integration in writing instruction, the Replacement, Amplification, and Transformation (RAT) framework has been employed to categorize teachers' TPACK (Hughes, 2005). The Replacement category involves technology use to replace existing teaching activities and resources without changing established instructional practices, student learning processes, or content goals (Hughes, 2005). The Amplification category focuses on technology use that enhances current teaching and learning practices. Increased efficiency and productivity are significant effects at this level. Finally, the Transformation category involves technology use that transforms the instructional method, the students' learning processes, and understanding of the subject matter (Hughes et al., 2006). For example, Hsieh and Tsai (2017) identified *using mobile technologies to meet student preferences* as the Replacement category, *conducting classes efficiently* and

invigorating/enhancing learning as the two Amplification categories, and *focusing on student ownership* and *extending learning* as the two Transformation categories. Previous research adopting the RAT framework to assess teachers' technological integration advocated that researchers need to explore teachers' rationales for using technologies at the Transformation level to promote the deep integration of technologies (Kimmons et al., 2015). In this study, the RAT framework provides the dimension for analyzing the levels of SVVR integration.

In summary, underpinned by the frameworks of teaching conceptions and RAT, this study mined two attributes from the interview transcriptions: one was the orientation of teaching conceptions and the other was the SVVR integration level of TPACK. We aimed to explore the association between the two to illustrate how teaching conceptions shape TPACK.

Methods

The research context

In recent years, SVVR has gained popularity in education because of its ease of use for teachers to make SVVR learning environments (Geng et al., 2021; Jong et al., 2020). The SVVR learning system was developed using EduVenture VR, which consists of an SVVR composer for teachers and a user interface for students (Geng et al., 2021). Figure 1 shows the structure of the SVVR system. The images in SVVR environments (as shown in Fig. 2) can immerse students in an authentic "field trip" experience for writing (Huang et al., 2020). Developers can also add human-computer interactions (e.g., voice prompts, tags, portals, single/multiple-choice questions, voice memos) to the SVVR environment to guide students' exploration and stimulate their thinking (Geng et al., 2021).
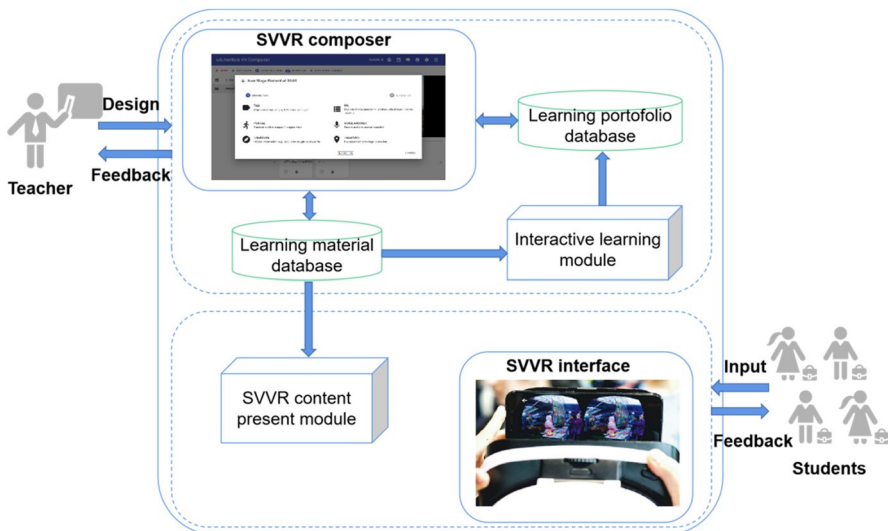

Fig. 1 SVVR-supported writing learning system

Fig. 2 Two scenes in SVVR environments

The participating school is considered an average school in Hong Kong, and Chinese is the medium of instruction. Using the EduVenture VR platform, the Chinese teachers from the school made the SVVR teaching materials and designed the lessons. The detailed procedure of the lesson development is described in Fig. 3. Supported by educational technologists and Chinese literature experts, the teachers discussed and explored worthwhile writing themes that reflected the cultural and sociohistorical significance of the local places in Hong Kong. They selected reading materials from the local Chinese literature about the chosen places, and created lesson materials (e.g., relevant textbook passages and worksheets). Based on the discussion, the teachers designed the lessons and created the SVVR learning environment in the SVVR composer (as shown in Fig. 4). Following the design stage, each of the teachers implemented the reading and writing lessons. The implementation stage of one teaching unit generally lasted 14–18 periods (one period is 45 min). The reading comprehension took eight to ten class periods, the writing session assisted by the SVVR took four to six class periods, and the evaluation and feedback took two periods.
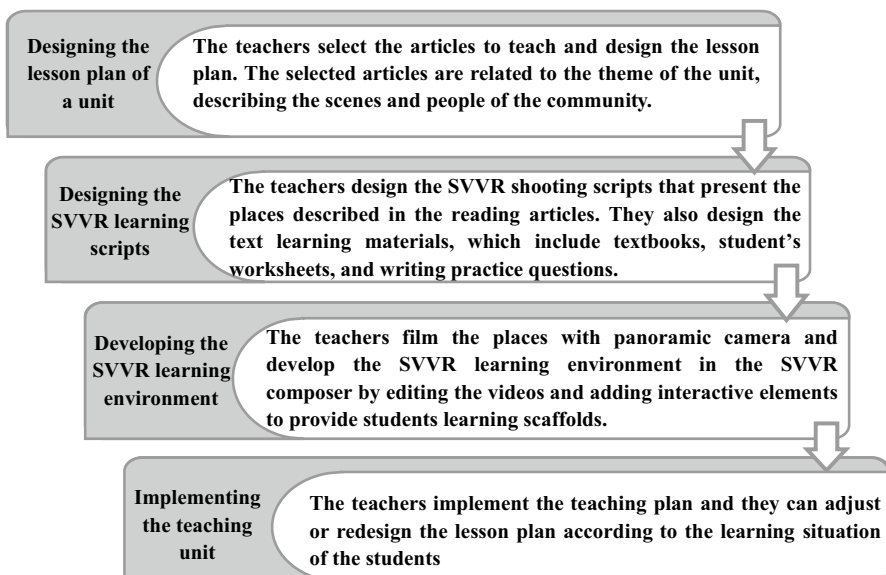

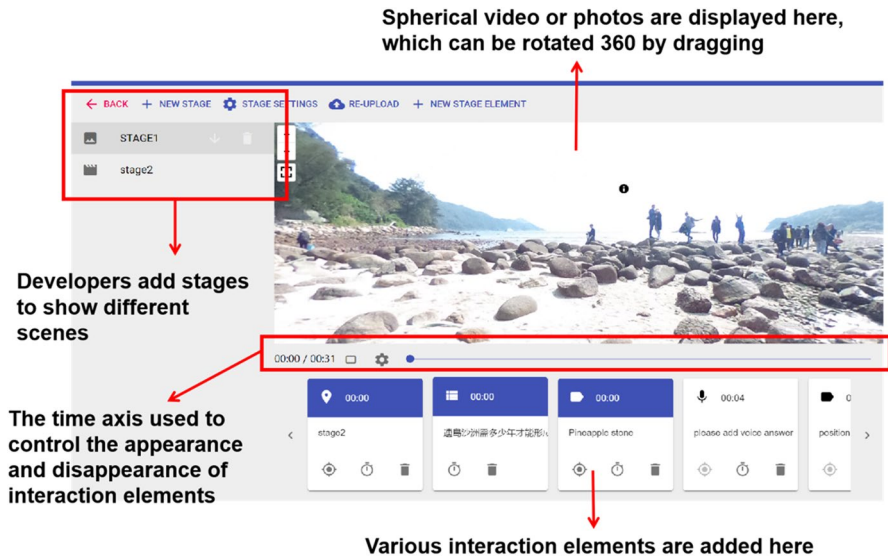**Fig. 3** Design and implement procedures of a VRWI unit

Fig. 4 The interface of the SVVR environment creation platform

Participants

This study adopted the purposive sampling method, and the sample was drawn from teachers who had implemented VRWI. Twenty-one grade 7–9 secondary teachers from the school participated in this study. Seven of the teachers were male (33%) and the average age of the participants was 32.3 ($SD = 8.7$). Six of them had a master's degree (29%), and the rest graduated with a bachelor's degree (71%). The teachers' names were replaced by numbers from 1 to 21 and were abbreviated as T1-21. Ethical approval to conduct the study was granted by the university's ethical approval committee. The researchers obtained the necessary signed consent forms from the teachers before data collection.

Data collection

Given the intention of this study, the researchers observed all the teachers' SVVR writing classrooms and then conducted individual interviews. The researchers also read the lesson plans and teaching materials before conducting the classroom observations. The researchers observed and recorded the teaching and learning activities, the interaction between teachers and students, students' performances, and the classroom settings (Schmidt-Crawford et al., 2016). The interview questions (see Appendix 1) formulated by emulating earlier research (Hsieh & Tsai, 2017; Lameras et al., 2012) sought to explore the teachers' subjective experience with VRWI and their explanations of the lesson design and implementation (Patton, 2014). The teachers were interviewed in Mandarin Chinese or Cantonese according to their preference, and each interview lasted between 45 and 60 min. The interviews were audio-recorded and transcribed verbatim.

After transcription, each participant reviewed the transcript of their interview and corrections were made, which improved the credibility of the data.

Data analysis

Identifying TPACK-related segments

The interview transcriptions were analyzed using content analysis (Mayring, 2015). The coding consisted of three phases. First, the transcriptions were divided into small segments (Boschman et al., 2014): units of descriptions or comments that expressed a key meaning of a specific topic about writing instruction, SVVR, or VRWI. The transcriptions were divided into 270 segments and then the segments related to TPACK (strategies or pedagogical affordances of SVVR use regarding teaching and learning writing) were identified. At the end of this round of coding, 245 segments related to TPACK were extracted. To qualify as a TPACK segment, the teacher's talk must account for how SVVR was used to anchor pedagogical activities that contributed to students' learning about writing. The following is an example of how T20 used SVVR to engage students in group discussions to generate writing themes.

> T20: After students observed freely in SVVR, I chose some scenes in the SVVR environment to let students observe together so that they could discuss what they saw and felt, and the group leader summarized the highlights of their observations. At the same time, I guided them to think carefully about the observations to construct the possible themes of their compositions.

Identifying the orientation of teaching conceptions

In the second phase, each of the segments related to TPACK was given a "conception orientation" code (i.e., skill-oriented, community-oriented, or identity-oriented) to mark teachers' underlying conceptions of VRWI. For example, the following segment was coded as "skill-oriented" because the teacher's teaching focus was writing skills.

> T7: SVVR can present scenes across time and space, the static scenes of the city, such as buildings, while SVVR videos can present dynamic scenes, such as people's movements. These scenes can be described respectively by static description, dynamic description, or the walking description method.

In the next example, the segment was coded as "community-oriented" to represent the teacher's teaching focus on using diverse students' perspectives to stimulate discussion as a classroom community.

> T15: I used SVVR to present writing materials for students to share and discuss with their classmates. When students saw some interesting scenes in the SVVR learning environment, they would immediately tell their classmates and discuss the unique views they observed in the scenes.

The next segment was coded as "identity-oriented" to represent the teacher's teaching focus on cultivating students' inner voices in their writing.

> T13: Perhaps it is a long journey to develop students' habits or ability to feel and think about the ordinary things in their life and to inspire their inner voices. It

requires our persistent efforts to encourage them to reflect and pay attention to small things in the SVVR, and it is also important to read and understand how local authors construct the significance of places with words in the articles.

Identifying the levels of TPACK regarding the SVVR integration

In the third phase of the analysis, each segment was classified into Replacement, Amplification, and Transformation to represent the level of SVVR integration based on the teachers' pedagogical reasons/purposes. For example, the following segment was coded as "replacement" because the teacher mainly used SVVR to replace the traditional manner of presenting writing content without improvement in the pedagogies or classroom activities.

T4: In previous classes, I used photos and videos to show students the scenes, and now I can use SVVR to show them scenes that can be described in their compositions.

The next segment was marked as "amplification" because the teacher tried to enhance students' learning effect, but did not change the pedagogical purposes.

T6: I used SVVR to present richer writing materials that stimulated students to describe the scenes. They saw richer and more vivid scenes in SVVR. They consequently had the desire to describe and were motivated to describe the scenes in more detail. You can see the improvement in their composition scores.

The next segment was marked as "transformation" because the teacher focused on using SVVR to present content that could be used to stimulate students' thinking and reflection about society, and then transform the pedagogical purpose of his previous writing lessons.

T12: SVVR can present scenes that students have never seen before. More importantly, we need to capture more scenes that have been described in the reading articles so that students can compare the similarities and differences between them, and then I would guide them to reflect on the reasons for the similarities and differences to stimulate deeper concern about society.

To improve the accuracy of the coding, a researcher who is a specialist in TPACK was invited to re-code the segments of approximately 20% of the transcripts. The reliability was calculated with a Cohen's Kappa of 0.79, which was deemed sufficient. After the three

Table 1 Counts of the segments that coded from the conception and TPACK perspectives	Count of TPACK segments
The orientation of conceptions	
Skill-oriented	78 (31.84%)
Community-oriented	110 (44.89%)
Identity-oriented	57 (23.27%)
Level of SVVR integration of TPACK	
Replacement	26 (10.88%)
Amplification	126 (52.72%)
Transformation	87 (36.40%)

phases of coding, 239 segments (six segments were not classified into the RAT framework because the pedagogical purposes were not clear) related to TPACK were coded from the perspectives of "conception orientation" and "level of TPACK" (see Table 1).

Exploring the association between teaching conceptions and TPACK

By coding the transcriptions of teachers' interviews, teachers' conceptions emerged through their descriptions of how they viewed VRWI, and TPACK emerged through their descriptions of how they designed and implemented VRWI. The teachers' conceptions of VRWI were identified as three orientations, namely skill, community, and (writer) identity, to show the teacher's teaching focus. The teachers' TPACK was classified into three categories, namely Replacement, Amplification, and Transformation, to indicate the level of integrating SVVR into their writing lessons.

The "conception orientation" and "level of TPACK" can be seen as ordinal categorical variables, with each one having three ordinal categories. Therefore, Spearman's Rho analysis (Croux & Dehon, 2010) was adopted to test the association between the "conception orientation" and "level of TPACK"; then Chi-square analysis and post hoc testing (Onchiri, 2013) were conducted to explore the group differences of the two variables. Furthermore, multivariate ordered logistic regression analysis (Fagerland et al., 2010) was adopted to find out how the teachers' TPACK actualized from different conception orientations differed in the level of SVVR integration. The analysis was conducted using the software, SPSS Statistics 25.0. The combination of these analysis methods quantified the association between "conception orientation" and "level of TPACK."

Results

Orientations of teaching conceptions manifested in the transcriptions

Skill-oriented conceptions

Table 1 shows the results of classifying the TPACK-related segments into "conception orientation" and "level of SVVR integration." Seventy-eight segments (31.84%) were classified as "skill-oriented." These teachers' TPACK focused on the pedagogies and strategies of teaching writing skills and other performances that could be measured by examination. For example, one teacher described how to teach writing skills.

> T8: I focus on using SVVR to present the highlights of the reading articles that use various writing skills. It is helpful for students to recite the key paragraphs and sentences after seeing the scenes in the SVVR environment to remember how authors use these writing skills to describe the scenes.

They also focused on using SVVR to present augmented content in an immersive environment that was contrasted with the traditional medium composed of text and ordinary pictures. In the following exemplar quote, the teacher describes how to enrich students' compositions and reinforce descriptive writing skills with SVVR.

T4: When students are observing in SVVR, it is important to remind them to write down details of what they see and hear, and to imagine what they might smell and touch, so that they can use multiple-sensory writing techniques in compositions.

In conclusion, the TPACK which was identified as "skill-oriented" focused on using SVVR to arrange learning activities for students to observe the world, accumulate writing materials, and practice writing skills.

Community-oriented conceptions

A total of 101 TPACK-related segments (44.89%) were classified as "community-oriented." The teachers' TPACK mainly focused on using SVVR to engage students in collaborative learning to transform the classroom from teacher-centric to student-centric. In the following two quotes, the teachers intended to organize group discussions and sharing activities and let students explore the SVVR environment autonomously.

T14: When students are immersed in SVVR, they have their own space, and they can explore freely, observe what they are interested in and go where they like. I seldom interfere with their observations and I mainly answer their questions about the observations and guide them to think more and discuss with their classmates.
TI5: I designed SVVR-based learning tasks for group cooperation and then divided the students into four learning groups. Each group had different tasks. Even though students looked at the same scenes, each person started from a different writing angle. The meaning of group discussion was to share their own opinions first and then discuss the differences between them.

In the next quote, the teacher explicated the pedagogical reasons for arranging group sharing activities.

T16: After a group reported on their SVVR observations, I asked the other students to find out the wonderful parts of what this group presented. In this process, students had to think about the ideas of other students, which was also very helpful for their understanding of the landscapes and also the reading articles.

In conclusion, the TPACK which was identified as "community-oriented" focused on using SVVR to make students think about the diverse meanings of the observed scene through independent exploration and collaborative learning. In this process, the pedagogical purposes of enhancing learning motivation, improving learning engagement, and deepening the understanding of learning content are achieved.

Identity-oriented conceptions

A total of 57 TPACK-related segments (23.27%) were classified as "identity-oriented." These teachers' TPACK focused on teaching strategies to solicit students' inner voices based on stimulating their feelings and thoughts about their lived experiences and society. Regarding the learning content, the teachers focused on using SVVR to present scenes with sociocultural significance. These scenes were described in Chinese literary works, and more importantly, there were subtle differences between the SVVR scenes and the authors' descriptions due to time changes and the authors' emotional processing. In this way, students had opportunities to compare two representations of the content depicted using two media (text and SVVR) which are essentially content knowledge

and technological content knowledge. Students contrasted their observations in SVVR with the text they read to enhance their understanding of the sociocultural connotations of places, and thus learned how to observe like writers. The teachers expected students to experience emotional changes and develop affection related to the local places.

> T2: My purpose in using SVVR was to present some scenes that are described by established authors in the text, especially to form a contrast of time and present the historical changes of a place. Only in this way can students be aware of the changes of the times and think from a perspective they have never considered before.

These teachers created situations to guide students to experience the process from emotional stimulation to deeper reflection, and finally to encourage students to formulate their own voices and thoughts. For example, some teachers used the close reading method to guide students to understand the affections and sociocultural connotations in the articles, while others aimed to promote students' reflection on constructing meaning for their relationship with the world. In the following two quotes, the teachers encouraged students to generate their own feelings and thoughts.

> T17: I used SVVR to improve students' understanding of the landscape and society, and then to inspire them to generate personal feelings from the observations. If we did not use SVVR, it was difficult for students to experience the world beyond the classroom and have new ideas to write in their own words.

Some teachers' TPACK focused on using SVVR to cultivate students' positive values, and took it as the basis to encourage students' articulation of their inner voices.

> T12: After observing SVVR, through my guidance, students can understand why the authors of the reading articles wrote in a certain way, and can understand the thoughts and affections conveyed in the articles by the authors. They need to understand pluralistic sociocultural significance before they can formulate their own ideas about the world.

Furthermore, the teachers focused on using SVVR to present scenes similar to or different from the students' lives. The purpose was to cultivate students' affection or reflection on the communities they live in. The corresponding TPACK refers to the use of SVVR to support students in shaping their own observing perspectives.

> T16: Some students live in the communities depicted by the SVVR environment and they noticed some details of the scenes they passed by many times but had never paid attention to. These details in the SVVR can inspire students to think more about their communities, and it is important for them to generate their own feelings and ideas, which can be refined in their writing topics.

Levels of TPACK regarding SVVR integration

Guided by the RAT framework, teachers' TPACK was classified into three levels, namely Replacement, Amplification, and Transformation. A total of 26 segments (10.88%) were identified as Replacement, while most were coded as Amplification ($N = 126$; 52.72%) and Transformation ($N = 87$; 36.40%).

TPACK classified as the replacement level

The teachers' TPACK was coded as the Replacement level when they used SVVR in their classrooms but did not change the established instructional practices, student learning processes, or pedagogical goals. For example, the TPACK segments were coded as Replacement when the teachers focused on the product of the writing and transmitted the writing content to students.

> T18: In fact, writing is a process from input to output. Students need more writing input, and reading articles is the main input to their writing. Using SVVR, students can see more of the world, but it will not help them to write beautiful words and phrases. So, I gave students more articles for reading and let them recite some key paragraphs.

The teacher's knowledge of presenting content with SVVR could be compared with that of traditional media. The TPACK identified as Replacement only focused on using SVVR to replace traditional means (e.g., text, two-dimensional pictures, and videos). However, these teachers did not expect to use SVVR for improving student learning.

> T9: SVVR was used to provide students with a fresh feeling because the spherical pictures are more vivid and attractive, but it was not useful for improving the writing performance since the students' vocabulary remained poor.

TPACK classified as the amplification level

The TPACK of the teachers was coded as Amplification when they focused on improving learning efficiency but retained the same pedagogical ends which focused on enriching the writing content (e.g., details of people and scenes, vocabulary, and sentences). At this level, the teachers began to focus on the learning process. Consequently, the pedagogy they designed was mainly for facilitating the process of students learning to write.

> T10: The pictures were shown to the students to make it easier and more efficient for them to understand the ways that other authors wrote. Students asked me how they could better describe the scene they had observed. This was extremely helpful for enriching vocabulary and learning descriptive skills.
>
> T11: When students observed in the SVVR, I guided them to pay more attention to details of scenes and people because they usually ignored these details, so they were not able to describe these details in their compositions. Using SVVR can really help me to teach them how to describe the details because I can guide them in the process of observation.

Driven by this teaching purpose, teachers' TPACK focused on using SVVR to complete teaching practices that enhanced students' learning such as activities (e.g., games and competitions) that increased their motivation and engagement in learning.

> T15: I think SVVR can be used to design gamified learning tasks based on students' observation and exploration using SVVR. For example, I designed a quick-answer game to encourage students to find more descriptive details from the SVVR environment and stimulate their imagination of taste, smell, and touch of

the scenes. In this way, I could increase students' participation and enhance their impressions of the scenes.

In conclusion, at this level, teachers' TPACK tended to use SVVR for enhancing students' learning effect. The teachers compared SVVR-based activities for learning writing with traditional approaches to advance the efficiency of the writing lessons.

TPACK classified as the Transformation level

Finally, the teachers' TPACK was coded as Transformation when they designed the lessons so as to transform the teacher-centric pedagogy and learning processes of passive acceptance. The TPACK that was classified into the Transformation level focused on strengthening students' thinking for writing (e.g., dialectical thinking, self-reflection, progressive and evolutionary historical view), and developing personalities (i.e., key learning points of values and moral characters; see Appendix 2). The following TPACK quote was coded as Transformation because the teacher aimed to cultivate students' thinking and, therefore, to help students form their ability to judge things independently.

> T17: By reading articles written by other authors, students compared the authors' descriptions with the scenes they saw in SVVR. I first guided students to understand other people's ideas, and then to reflect on their own ideas. Students need to have dialectical thinking in this process and they will know that different people will have different views and feelings towards one thing because of the different standpoints, and our preconceived ideas are not necessarily the best. Other people's ideas are also not necessarily the only worthy ideas.

The teachers' TPACK focused on using SVVR to significantly redesign and even create new teaching activities that could change or expand students' thinking. Given the affordance of SVVR for students to formulate individual perspectives, the teacher fostered individualized development by offering individualized guidance for the students' writing.

> T17: With SVVR, students had their own independent space and were completely autonomous. This permitted the emergence of differences in learning by individuals. Usually, without giving any instructions, I let the students observe freely according to their own interests and record their observations on the worksheets. When they were observing, I checked each student's worksheet, then I could make the best use of the SVVR circumstances according to their aptitude.
> T20: After students observed in SVVR, I kept asking them to think carefully about the meanings of the scenes and social phenomena, and provided individual guidance to help them construct the themes of their compositions.

In essence, TPACK transformed the meaning of writing instruction by cultivating the students to be authors with independent thinking and unique views. This included teaching students to understand other authors' ideas and reflect on their own thoughts through observing the SVVR environment. Consequently, the students learned how to observe places and people the way an established writer would.

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Table 2 Distribution of the TPACK levels in different conception orientations

	TPACK level			Sum
	Replacement	Amplification	Transformation	
Conception orientation				
Skill-oriented				
Observed Count	25	52	0	77
Expected count	8.4	40.6	28.0	77.0
% within conception orientation	32.5%	67.5%	0.0%	100.0%
% within level of TPACK	96.2%	41.3%	0.0%	32.2%
Community-oriented				
Observed Count	1	69	35	105
Expected count	11.4	55.4	38.2	105.0
% within conception orientation	1.0%	65.7%	33.3%	100.0%
% within level of TPACK	3.8%	54.8%	40.2%	43.9%
Identity-oriented				
Observed Count	0	5	52	57
Expected count	6.2	30.1	20.7	57.0
% within conception orientation	0.0%	8.8%	91.2%	100.0%
% within level of TPACK	0.0%	4.0%	59.8%	23.8%
Sum				
Observed Count	26	126	87	239
% within conception orientation	10.9%	52.7%	36.4%	100.0%
% within level of TPACK	100.0%	100.0%	100.0%	100.0%

The association between teaching conceptions and TPACK

Through the three phases of coding, the quantitative relationship between the teachers' conceptions and TPACK was established. The observed counts and expected counts were calculated and presented in the cross-tabulations table (see Table 2).

Results of Spearman's rho

Spearman's Rho analysis was adopted to measure the strength of the correlation between "conception orientation" and "level of TPACK." The results showed that the correlation coefficient of Spearman's Rho analysis was 0.731 ($p < .01$), which indicated a significant positive correlation between the two variables, and the correlation was relatively strong (Croux & Dehon, 2010).

The Chi-square analysis

A Chi-square analysis can only be conducted when the expected counts in all cells are greater than 5 or when the proportion of the cells containing a count of less than 5 does not exceed 20% (McHugh, 2013). From Table 2, it can be seen that the minimum expected frequency was 6.2, indicating that the sample size was large enough to conduct Chi-square

Table 3 Adjusted standardized residuals between the conception orientation and TPACK level groups

	TPACK level		
	Replacement	Amplification	Transformation
Conception orientation			
Skill-oriented			
Count	25	52	0
ASR	*7.4**** (Positive correlation)	*3.2**** (Positive correlation)	*−8.1**** (Negative correlation)
Community-oriented			
Count	1	69	35
ASR	*−4.4**** (Negative correlation)	*3.6**** (Positive correlation)	−0.9
Identity-oriented			
Count	0	5	52
ASR	*−3.0**** (Negative correlation)	*−7.6**** (Negative correlation)	*9.9**** (Positive correlation)

***p < .001

analysis. The Chi-square values of the two variables were 151.52 ($p < .001$), also indicating a significant correlation between the "conception orientation" and "level of TPACK." Cramer's V is a measure that provides an estimate of the strength of the association between variables. In this study, Cramer's V was 0.56 ($p < .001$), which indicated that the correlation was strong.

The adjusted standardized residuals (ASRs) (see Table 3) were then calculated to explore the group differences that exist in the variables (McHugh, 2013). Normally, when the absolute ASR value is greater than 2, the difference between the observed count and the expected count can be considered to be statistically significant. Due to the multiple comparisons involved in the present study, to estimate more conservatively, the absolute ASR value was chosen to be bounded by 3 and −3.

The results showed that the "level of TPACK" of the teachers with skill-oriented conceptions was likely to be at the Replacement (ASR = 7.4) and Amplification levels (ASR = 3.2). In addition, skill-oriented conceptions were positively correlated with the Replacement more than the Amplification level of TPACK. On the contrary, skill-oriented conceptions were negatively correlated with the Transformation level of TPACK because the ASR was negative, and its absolute value was far below 3 (ASR = −8.1).

In the same way, the community-oriented conceptions were positively correlated with TPACK at the Amplification level (ASR = 3.6) and were negatively correlated with TPACK at the Replacement level (ASR = −4.4). Similarly, identity-oriented conceptions were positively correlated with TPACK at the Transformation level (ASR = 9.9) but were negatively correlated with TPACK at the Replacement (ASR = −3.0) and Amplification (ASR = −7.6) levels.

Multivariate ordinal logistic regression

The results of multivariate ordinal logistic regression revealed the effect of "conception orientation" on the "level of TPACK." First, the results of the parallel line test

Table 4 Estimate of parameters of the association model of conception orientation and TPACK level

	Estimation
Threshold	
TPACK level = Replacement	− 8.458***
TPACK level = Amplification	− 2.342***
Location	
Conception orientation = Skill-oriented	− 7.740***
Conception orientation = Community-oriented	− 3.367***
Conception orientation = Identity-oriented	0[a]

[a] means this parameter is redundant and therefore set to zero

***p<.001

showed that the parallelism hypothesis was valid ($\chi^2 = 0.905$, $p = .636 > .05$), which meant the regression equations are parallel to each other and can be analyzed by the ordinal logistic process. The model fitting parameter indicated that the model was statistically significant ($\chi^2 = 182.052$, $p < .001$).

The estimate of the parameters of the model (see Table 4) showed that the effect was significant ($p < .001$). The results also showed that the probability of skill-oriented conceptions-related segments being classified as the higher RAT levels (Amplification and Transformation) is 0.0004 (EXP (− 7.740)) times the number of identity-oriented conceptions-related segments. Similarly, the probability of community-oriented conceptions-related segments being classified as higher RAT levels (Amplification and Transformation) is 0.034 (EXP (− 3.367)) times the number of identity-oriented conceptions-related segments. This meant that the sophisticated conceptions-related segments were more likely to be classified as the higher levels of TPACK.

Conclusion and discussion

This study explored the association between teaching conceptions and TPACK to reveal the associations by which conceptions were actualized in the knowledge of SVVR-supported writing instruction. The qualitative results illustrate the purposes, methods, and effects of teachers using SVVR in writing lessons. The quantitative results can be summarized as follows: teachers who hold the most sophisticated conceptions of VRWI (i.e., identity-oriented conceptions) shape their TPACK at the Transformation level of SVVR integration. It means they pay more attention to using SVVR for cultivating students' inner voices, cultural awareness, collaborative working, and autonomous learning, which encourages them to become writers in their own right. More specifically, identity-oriented conceptions trigger Transformation and will not trigger the Replacement or Amplification level of TPACK in the current educational context. On the contrary, the skill-oriented conceptions trigger more Replacement than Amplification, and that is unlikely to trigger the Transformation level of TPACK. Community-oriented conceptions trigger Amplification and are unlikely to trigger the Replacement level of TPACK. In conclusion, advanced teaching conceptions trigger deeper integration of

SVVR into teachers' design of VRWI. This study reveals the underlying reason for the level of SVVR integration in teachers' TPACK from the lens of teaching conceptions.

Teaching conceptions as the underlying perspective that shapes TPACK

While literature suggests that curriculum design is influenced by TPACK (Markauskaite & Goodyear, 2018; Saudelli & Ciampa, 2016; Tseng et al., 2020), the underlying perspective that teachers have of curriculum design is less understood. With respect to this issue, Boschman et al. (2014) attributed the formulation of TPACK in part to the accumulation of experience in designing and implementing learning activities. The findings of this study further indicate that the teachers' TPACK for designing VRWI is shaped by teaching conceptions. The actualization of teachers' conceptions in TPACK is most likely through the way in which teachers set pedagogical goals based on their conceptions and thereby accumulate the teaching and learning strategies taken to achieve these goals. Consequently, the conceptions gradually shape teachers' TPACK in teaching practice.

The results suggest that advancing teaching conceptions can be seen as a key to improving teachers' TPACK. Teachers with identity-oriented conceptions of VRWI focused on cultivating students' own unique ideas through student-centered pedagogy, and thus always tried to find ways to orchestrate and coordinate technology, pedagogy, and content into every act of teaching. They created SVVR scenes to engage students in making meaning of the reading materials and to foster their socioemotional connections to the places. As researchers have pointed out (Roussinos & Jimoyiannis, 2019; Swallow & Olofson, 2017), the aspiration of pedagogical goals stimulates teachers' knowledge of repurposing and redefining innovative technologies in a specific educational context. The teachers flexibly navigated the affordances and constraints of each technology and each possible teaching approach to find solutions that effectively integrated writing, pedagogy, and SVVR. The employment of SVVR technology enables these teachers to create teaching strategies to cultivate students' inner voices and guide them to achieve a sense of writer identity.

Furthermore, the results of this study show that a change in educational goals based on advanced conceptions will shape the formation of teachers' TPACK in the Transformation category. Transformation, in the context of this study, refers to the shift in teaching focus from writing skills and flowery words to students' unique and creative ideas, and from a pedagogy based on practice and memorization to a student-centered pedagogy that inspires students to become future writers. The knowledge that is classified into the Transformation level and is identity-oriented expands the content of TPACK in the context of SVVR-supported writing instruction. The finding provides teacher educators with further insights into the formulation of the goals for professional development activities. It, therefore, provides a new way to strengthen the integration of technology in teachers' instructional design and classroom practice.

The shift from a focus on the denotation to the connotation of TPACK

In the research on TPACK, researchers have extended the TPACK framework from different perspectives (e.g., TPACK constructs, subject domain, target groups, various technology tools) and associated it with demographic variables, technology usage experience,

technology integration self-efficiency, technology literacy, professional development status, attitude and behavior intention and so on (Cheah et al., 2019; Cheng, 2017; Durak, 2021, Koh et al., 2014; Tai, 2015). This study explored the immanent cause of technology integration level in the teachers' TPACK from the perspective of teaching conceptions. It also explored the actualization of teaching conceptions in TPACK to present the essence of teachers' design and implementation regarding VRWI. To this end, this study traced the pedagogical reasons for the integration of SVVR embodied in teachers' TPACK from the perspective of teaching conceptions. Although teachers' teaching conceptions, for the most part, are the foundations of their decisions and actions in the classroom, researchers have always pointed out that sophisticated understanding of subjects and teaching is not enough to ensure the straightforward translation of conceptions into practice (Kong, 2018; Southerland et al., 2003). This study offers an explanation and justification for regarding TPACK as the manifestation of teaching conceptions.

The results reveal how different oriented teaching conceptions shape teachers' TPACK into corresponding levels of SVVR integration. This study fuses and extends the frameworks of teaching conceptions and TPACK. The results can inspire teacher educators to view teachers' pedagogical design knowledge regarding integrating technologies from the perspective of teaching conceptions. The participating teachers' experience of VRWI also provides teaching strategies and knowledge for educators who are concerned with SVVR-supported writing learning.

Limitations and future research directions

This study acknowledges several limitations and needs further research efforts. First, the participants were experienced Chinese teachers from the same school, led by a highly dedicated Chinese teacher who is also an established writer. The findings may not, therefore, be generalizable to other Chinese teachers. Future studies could apply the data collection and analysis methods to other contexts, to investigate whether the association between teaching conceptions and TPACK also exists when teachers from other schools and districts teach writing with SVVR. Second, although the researchers read the teachers' lesson plans and observed their classrooms to understand their TPACK more accurately, the data source was mainly the teacher interviews. In future research, coding more information sources (e.g., lesson plans, reflection notes, and classroom recordings) would provide more elaborated conclusions regarding this research topic.

The study results reveal several directions for future research. First, based on the advanced conceptions and TPACK identified in this study, teacher educators can develop teacher education programs regarding the use of SVVR in writing instruction. Second, the results of this study summarized the hierarchical levels of SVVR integration into the writing classroom. Researchers can also design and apply the assessment criteria of teachers' design and practices of VRWI based on the results. In addition, future research can systematically explore the internal mechanism of the effect of teaching conceptions on TPACK. Specifically, the study results lead to a future research question: What are the key internal and contextual factors influencing how teachers actualize their teaching conceptions? Understanding how teachers' conceptions of VRWI are implemented is significant for inspiring and improving teachers' integration of SVVR into writing instruction. This research question can also be extended to the application of other innovative technologies in writing instruction.

Appendix

Appendix 1
   The interview questions for teachers:

A) Why did you decide to use SVVR in writing instruction?
B) What is the role of SVVR in your writing instruction?
C) What are the differences between SVVR writing classrooms and your previous writing classrooms?
D) Could you explain your design and implementation of VRWI in detail? (the authors asked follow-up questions based on the classroom observation)
E) Could you describe the success and failures of your SVVR writing courses (from the perspectives of teaching design, implementation, and the impact on student learning)?
F) What are your opinions on the benefits and challeng es of VRWI?

   Appendix 2
   See Appendix 2 Table 5.

Table 5 The key learning points of values and moral characters of Chinese language in Hong Kong

Positive values and moral character		Positive attitudes
Individual	Community	
Core values	*Core values*	Optimism
Sanctity of Life	Equality	Enjoying participation
Truth	Goodness	Discriminating wisely
The appeal of beauty	Benevolence	Originality
Sincerity	Kindness	Appreciation
Human dignity	Liberty	Empathy
Rationality	Common well-being	Concern
Creativity	Helping and supporting each	Positivity
Bravery	other	Confidence
Freedom	Righteousness	Cooperation
Affection	Trust	Taking responsibility
Personal uniqueness	Interdependence	Adaptability
	Sustainability	Being open to the outside world
	The overall well-being of	Respect
	mankind	–oneself
		–others
Auxiliary value	*Auxiliary value*	–life
Self-esteem	Pluralism	–quality and excellence
Self-communion	Due process of law	–evidence
Self-discipline	Democracy	–justice
Self-cultivation	Common will	–law
Ethics	Patriotism-centered national	–different lifestyles, beliefs and views
Self-determination	spirit	–environment
Open-mindedness	Tolerance	Enjoying learning
Independence	Equal opportunities	Diligence
Aggressiveness	Culture and civilization	
Integrity	inheritance	
Earthiness	Divine sovereignty and	
Sensitivity	human responsibility	
Modesty	Sense of belonging	
Perseverance	Being united as one	

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Data availability There is no data available in this study.

Declarations

Conflict of interest The authors have not disclosed any competing interests.

Ethical approval Ethical approval to conduct the study was granted by the university's ethical approval committee.

Participants consent statement The researchers obtained the necessary signed consent forms from the teachers before data collection.

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Mengyuan Chen is an intermediate assistant research fellow in the Advanced Innovation Center for Future Education, Faculty of Education, Beijing Normal University. Her research interests include computer assisted language learning, technological pedagogical content knowledge, and application of virtual reality in education.

Ching-sing Chai is the associate dean of the Faculty of Education, The Chinese University of Hong Kong. He is also an professor in the Department of Curriculum and Instruction & Centre for Learning Sciences and Technologies, The Chinese University of Hong Kong. His research interests include teacher education, technological pedagogical content knowledge, teacher beliefs, and ICT in education.

Morris Siu-Yung Jong is an associate professor in the Department of Curriculum and Instruction; director of the Centre for Learning Sciences Technologies, The Chinese University of Hong Kong. His research interests include e-Learning, educational gamification, virtual/augmented reality in education, mobile learning, STEM education, teacher professional development on technology-enhanced pedagogies.

Authors and Affiliations

Mengyuan Chen[1,2] ⬤ · **Ching-sing Chai**[3] · **Morris Siu-Yung Jong**[3]

✉ Mengyuan Chen
   chmyonly@sina.com

   Ching-sing Chai
   CSChai@cuhk.edu.hk

   Morris Siu-Yung Jong
   mjong@cuhk.edu.hk

[1]   Advanced Innovation Center for Future Education, Faculty of Education, Beijing Normal University, Beijing, China

[2]   Center for Educational Science and Technology, Institute of Advanced Study in Humanities and Social Sciences, Beijing Normal University Zhuhai Campus, Zhuhai, China

[3]   Department of Curriculum and Instruction and Centre for Learning Sciences and Technologies, The Chinese University of Hong Kong, Hong Kong, China