Flipped classroom: motivational affordances of spherical video-based immersive virtual reality in support of pre-lecture individual learning in pre-service teacher education

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Abstract
Flipped classroom (FC) is a “blended” instructional approach that requires students to complete pre-lecture individual learning tasks in preparation for participating in related in-lecture peer learning activities. One of the critical problems of FC has been students’ lack of motivation to complete the assigned online pre-lecture tasks prior to attending the corresponding face-to-face lectures. Spherical video-based immersive virtual reality (SV-IVR), which can be produced without costly computing equipment and sophisticated technical expertise, is a technological tool with considerable potential for enhancing teaching and learning. This mixed-methods study was grounded in the instructional motivation theory of ARCS (Attention, Relevance, Confidence and Satisfaction). A total of 188 education students (i.e., pre-service teachers) who were generally knowledgeable about the pedagogical concept of FC evaluated the ARCS motivational affordances of SV-IVR in support of the pre-lecture stage of FC. These students were from teaching majors of (i) language education, (ii) social and humanities education, and (iii) mathematics and science education. The results indicated the participants across the 3 majors positively perceived SV-IVR as having desirable benefits on “A,” “R,” and “S,” but not “C.” This research provides new insights into adopting SV-IVR in FC, in particular, shedding light on leveraging this technological tool in pre-service teacher education.

Keywords  Spherical video-based immersive virtual reality (SV-IVR) · 360-degree videos · Flipped classroom (FC) · Teacher education · Pre-service teachers · Motivational affordances · ARCS
Flipped classroom (FC), a “blended” instructional approach that has been promoted in K-12 and higher education since the mid-2010s, is a key research area in the domain of technology-enhanced teaching and learning (Akçayır et al., 2018; Fox et al., 2019; Lo et al., 2021; O’Flaherty et al., 2015; Song et al., 2017; Jong 2017, 2019a). In the context of higher education, FC interchanges the conventional use of during-lecture and off-lecture time. Students are first requested to conduct pre-lecture, online individual learning outside the classroom (typically, watching instructional videos posted on the learning management system [LMS]) and then take part in related in-lecture, face-to-face peer learning in the classroom (Hwang et al., 2015). However, one of the critical problems of FC noted by higher-education instructors is students’ lack of motivation to complete the assigned online pre-learning tasks prior to attending the corresponding face-to-face lectures (Bai et al., 2020; Howitt et al., 2015; Huang et al., 2018; Lee et al., 2019; Jong, 2019b).

In the EDUCAUSE Horizon Report 2019, immersive virtual reality (IVR) is described as one of the salient technologies to be widely adopted in higher education in the 2020s (Alexander et al., 2019). Different from typical “non-immersive” virtual reality (or commonly termed “desktop VR”) which is viewed and controlled through a computer monitor and mouse (Lee et al., 2010; Moro et al., 2017), IVR “teleports” users to an immersive virtual world where they can freely navigate through head-mounted displays (HMDs) by using their own head movements (Fromm et al., 2021; Shadiev et al., 2021). In the recent decade, research has reported that the educational use of IVR can significantly promote learners’ motivation in the course of individual learning and, in turn, their learning engagement (e.g., Bower et al., 2020; Innocenti, 2017; Makransky et al., 2019; Passig et al., 2016).

In general, IVR consists of sophisticated three-dimensional computer-generated imagery (Bower & Jong 2020; Roche et al., 2021) that enables users to contextually experience situations that are not normally nor easily accessible in the real world, such as tracking whales along their migratory path across the Pacific Ocean (Southgate et al., 2019). Nevertheless, specific devices for accessing IVR can be costly and the development of IVR is capital- and technologically demanding, hindering its wide adoption in the field of education (cf., the prevalence of IVR in digital gaming and entertainment industries) (Geng et al., 2017; Sato et al., 2018; Jong et al., 2020a). Spherical video-based IVR (SV-IVR), which is an emerging subset of IVR, provides educational practitioners with an affordable and pragmatic means of providing learners with immersive learning experiences (Chang et al., 2020; Chen et al., 2021; Chien, 2020; Geng et al., 2021; Wu et al., 2021). Unlike computer-generated imagery IVR, an educator can easily and independently create SV-IVR by using an affordable customer-grade 360-degree camera (costing approximately US$300) and learners can conveniently access the SV-IVR on his/her own mobile phone using additional but inexpensive cardboard goggles (costing approximately US$5).

This study evaluated the motivational affordances of SV-IVR in supporting the pre-lecture stage of FC in the context of higher education, with pre-service teacher education as the particular focus. Grounded in the instructional motivation theory of ARCS (Attention, Relevance, Confidence and Satisfaction) (Keller, 1999, 2008,
2010), this research probed the motivational affordances of this technology perceived by pre-service teachers who (1) were familiar with the pedagogical concept of FC, and (2) participated in a 3-week FC setting in which SV-IVR was adopted to support their pre-lecture individual learning. The remainder of this article is structured as follows. The next section presents the related works on which this study is based. The research design and results are then described and discussed in detail. Finally, the article will be concluded with the implications and limitations of the present work, as well as avenues for future research.

Related works

Flipped classroom (FC)

The use of LMSs has proliferated in higher education, fueled by the accessibility of video-recording devices (e.g., built-in cameras in desktops, laptops, tablets, and mobile phones). FC has received increasing attention from educational researchers and practitioners, becoming something of a ‘buzzword’ in the mid-2010s (Akçayır et al., 2018; Bond 2020; Cheng et al., 2019; Jiang et al., 2020). As implied in the name, FC flips the teaching and learning activities that are traditionally held inside and outside the classroom (Bergmann et al., 2015, Howitt et al., 2015; Hwang et al., 2019). In general, from the practical perspective, the implementation of FC entails the combination of (1) pre-lecture, individual video-based learning in the form of “online homework,” and (ii) in-lecture, group-based peer learning in the form of “face-to-face classwork” (Lo et al., 2021; Song et al., 2017; Jong 2017, 2019a).

From the academic perspective, FC researchers have yet to agree on a theoretical definition of this “blended” instructional approach (Jong et al., 2022). However, according to a number of recent scoping and systemic reviews on the adoption of FC in K-12 and/ or higher education (e.g., Akçayır et al., 2018; Bond 2020; Cheng et al., 2019; Jiang et al., 2020), operationally, many scholars have adhered to the FC conceptual framework introduced by Hwang et al., (2015) in the pedagogical design of in-class and off-class learning activities in FC-related empirical studies (as is the case for this study). Theoretically grounded in the revised Bloom’s Taxonomy of Anderson et al., (2001), Hwang et al. conceptualised the pedagogical flow of FC with the 6 cognitive learning processes of “remember,” “understand,” “apply,” “analyse,” “evaluate,” and “create.” In the framework, the pre-lecture stage of FC focuses on engaging students in lower-order individual learning that entails tasks based on memory and comprehension, whereas the in-lecture stage of FC centres on engaging students in higher-order peer learning, with tasks based on application, analysis, evaluation, and creation.

Although significantly positive evidence regarding improved learning outcomes (such as academic performance, self-efficacy, critical thinking, collaboration, inquiry reasoning, etc.) resulting from FC has been reported (Akçayır et al., 2018; Bond 2020; Cheng et al., 2019; Jiang et al., 2020; Jong et al., 2022), one of the critical problems of FC noted by higher-education instructors has been students’ unmotivated attitude towards completing assigned online pre-learning tasks prior to attending the corre-
Spherical video-based immersive virtual reality (SV-IVR)

SV-IVR virtually places a person at the centre of a 360-degree human-recorded real-world environment where they can freely navigate in any direction using their head movements (Higuera-Trujillo et al., 2017; Kavanagh et al., 2016; Shadiev et al., 2021). SV-IVR can be easily accessed using a mobile phone and low-cost cardboard goggles (see Fig. 1). Possessing the advantages of being inexpensive, handy, and having easy-to-create features, SV-IVR is a useful tool for educators who may not be ‘tech-savvy’ but are eager to offer learners technology-supported immersive experiences in the process of teaching and learning (Chen et al., 2021; Geng et al., 2017; Kosko et al., 2021; Roche et al., 2021; Sato et al., 2018).

The educational use of SV-IVR, which is still an emerging research area in the field of IVR in education, requires further research efforts (Bower & Jong, 2020; Roche et al., 2021; Shadiev et al., 2021). In 2020 and 2021, a number of seminal works have reported positive evidence in this research area in a number of important journals of technology-enhanced teaching and learning. For example, in K-12 education, Chang et al., (2020) employed SV-IVR to facilitate students to carry out individual virtual fieldwork in elementary-level natural science education. Chien et al., (2020) leveraged SV-IVR to support students in conducting peer-assessment exercises in high-school language education. Jong et al. (2020) harnessed SV-IVR to integrate immersive and interactive virtual inquiry-based fieldwork into learning and teaching of physical geography in secondary schools. As for higher education, Lin et al.,
(2021) developed an SV-IVR-based self-directed learning kit for directing university freshmen in accessing library resources. Wu et al., (2021) to support self-regulated learning in a university art history course. Lin et al., (2021) studied the effects of university students’ multi-modal interactions with SV-IVR in the context of dyadic second language learning. Ulrich et al., (2021) compared the learning effectiveness of SV-IVR and ordinary videos in the context of medical education. Although the research settings of these studies were not FC-related, the positive learning outcomes (e.g., knowledge acquisition, enhanced learning motivation and engagement, and improved observational skills) resulting from the adoption of SV-IVR form a significant basis for further investigation into the use of this technological tool in FC.

As for pre-service teacher education, Roche et al., (2021) argued that SV-IVR can be a potentially fruitful tool for (1) supporting online virtual internships, and (2) documenting pre-service teachers’ teaching proceedings during their teaching practicums to facilitate post-teaching reflective and diagnostic activities. However, they cautioned that SV-IVR is not a “magical” tool. Its use in pre-service teacher education must be carefully planned to prevent it from becoming another “disruptive” tool that emphasises only practical usage without having pedagogical design; otherwise it will show education students a bad model of technology-enhanced teaching and learning. In fact, research into the educational use of SV-IVR in pre-service teacher education is still in its infancy (Kosko et al., 2021; Shadiev et al., 2021) and studies applying SV-IVR to support education students in FC settings are lacking (Fromm et al., 2021). The present work aimed to address this research gap, with the particular focus on leveraging SV-IVR to motivate pre-service teachers to conduct individual learning during the pre-lecture stage of FC.

ARCS instructional motivation theory

Researchers in cognitive sciences (e.g., Cordova et al., 1996; Malone 1981; Martin et al., 2014; Ryan et al., 2000; Schuuk et al., 2008) theorised the term “motivation” to explain humans’ behaviour of desire and reluctance—in particular, their willingness or unwillingness to do or commit to do something. From the view of education, “arousing and sustaining learners’ motivation” is always an essential consideration when designing and implementing an educational activity (Chiu et al., 2020; Mayer, 2019; Plass et al., 2020).

Keller (1999, 2008) argued that, in the instructional process, inducing and maintaining learners’ curiosity is the key to stimulating their learning motivation. Thus, engaging learners in an instructional environment is instrumental in forging a connection between learners’ interest and the intended educational goals, regardless of whether the mode of instruction is face-to-face or online, instructor-led or self-directed, or individual or group-based. Keller developed the 4-construct theoretical framework of ARCS to conceptualise learners’ motivation from the perspective of instructional sciences. Attention (A) refers to how effectively an instructional process captures learners’ interest, stimulates their thinking, and retains their attention. Relevance (R) pertains to how effectively an instructional process provides learners with learning experiences related to the real world and their personal needs. Confidence (C) reflects the ability of an instructional process to engender self-possession
in learners in relation to their capability to achieve their learning goals. Satisfaction (S) refers to the ability of an instructional process to induce feelings of satisfaction and gratification in learners. Furthermore, based on ARCS instructional motivation theory, Keller (2010) developed and validated the Instructional Materials Motivation Survey (IMMS), which is used for quantitatively gauging the motivational affordances of instructional materials from the view of learners in accordance with the 4 ARCS constructs. The overall Cronbach’s α of the instrument was 0.96; the individual Cronbach’s α of each dimension ranged from 0.81 to 0.92. To date, ARCS instructional motivational theory has been one of the most widely adopted theories in educational research related to learners’ motivation in various settings (e.g., conventional teaching methods and learning contexts [e.g. Kurt et al., 2017] and technology-supported learning environments [e.g., Turel et al., 2018]) and at different education levels (e.g., primary education [e.g., Jong 2020b], secondary education [e.g., Wah 2015], and higher education [e.g., Daugherty 2019]).

Yang (2017) applied Keller’s ARCS instructional motivation theory (1999, 2008) to investigate SV-IVR’s motivational affordances in facilitating senior secondary students in conducting virtual geography fieldwork (not in an FC setting). In the study, Yang modified Keller’s (2010) original IMMS questionnaire to reflect SV-IVR features and the research setting. The modified questionnaire consisted of 20 items, with 5 items for every construct. Yang validated the questionnaire; the overall Cronbach’s α was 0.97, and the individual Cronbach’s α of each construct ranged from 0.82 to 0.90. In the present study, another modified version of Yang’s IMMS questionnaire was developed to measure the motivational affordances of SV-IVR in supporting the pre-lecture stage of FC in the context of pre-service teacher education.

**Method**

**Research participants**

This study was conducted in a university offering teacher education programmes in Hong Kong. The research participants comprised education students (i.e., pre-service teachers) who (i) were pursuing the postgraduate secondary teacher preparation programme in the university and (ii) attended a 10-week generic course, namely, Teaching and Learning with Technology (TLT; quota of 50 enrolments per cohort) taught by the same instructor in 4 consecutive cohorts. Before attending this course, all the participants had experienced FC in the role of learners during their undergraduate studies or in other courses in the same programme. The number of students enrolled in TLT across these 4 cohorts was 48, 46, 50, and 44, respectively. Thus, the total number of participants in this study was 188 (aged 25.2 years on average); 65 were majoring in language education, 61 in social and humanities education, and 62 in mathematics and science education. The 3-week research manipulation was enacted in this course.
Review panel

An external 6-person review panel was formed for this study. The panel was composed of an E-learning professor from a regional university, an education professor in a local university, an educator from a local flipped learning teacher association, and 3 senior secondary teachers (with 12 to 15 years of teaching experience) of language education, social and humanities education, and mathematics and science education, respectively. In addition to scrutinising the data collection instruments used in this study, the panel was responsible for advising and validating the research manipulation design. The panel reviewed the self-accessed instructional materials developed to support the pre-lecture individual learning tasks to ensure they were:

1. aligned with the instructional paradigm of the outside-the-classroom stage of the FC conceptual framework of Hwang et al., (2015), i.e., the major pre-learning tasks only entailed the cognitive processes of remembering and understanding; and.
2. understandable to the participants from different teaching majors, in that they were able to comprehend the learning content and context of the materials.

Research manipulation

TLT, which is a generic course (irrespective of teaching majors) in the aforementioned programme, is composed of 10 weeks of 2-hour face-to-face lectures held weekly. The course introduces pre-service teachers to various technologies being pedagogically adopted in local secondary schools. A number of topics regarding the educational use of technological tools are explored and discussed in this course; one such topic is “Harnessing Mobile Devices in Classroom Teaching and Learning.” The course instructor typically spends 3 face-to-face lectures (viz. Lectures X, Y, and Z) in 3 consecutive weeks (viz. Weeks X, Y, and Z) covering the pedagogical adoption of in-class mobile learning using (i) Kahoot! (https://kahoot.it/), (ii) Nearpod (https://kahoot.it/), and (iii) Google Classroom (https://classroom.google.com/), respectively. The research manipulation of this study was enacted on the specifically designed pre-lecture individual learning tasks pertaining to Lectures X, Y, and Z in an FC setting grounded in the FC conceptual framework of Hwang et al., (2015).

Three sets of self-accessed instructional materials were developed to support the participants in completing the pre-lecture learning tasks before Lectures X, Y, and Z. These tasks cognitively situated the participants in SV-IVR, where they were required to observe the practical use of the 3 mobile learning platforms in an authentic classroom teaching and learning setting. They could then preliminarily (i) know (i.e., remember) the platforms’ pedagogical functions and (ii) comprehend (i.e., understand) the pedagogical advantages and disadvantages. Each material set was composed of (i) a 15-minute SV-IVR clip and (ii) an online form with which the participants described and explained what they observed in the clip. Five days before Lectures X, Y, and Z, the corresponding material sets were posted on the course LMS. The participants could access the SV-IVR clips using their mobile phones and the provided head-mounted cardboard goggles (see Fig. 1).
The SV-IVR clips in the three material sets were produced using an SV-IVR camera (Ricoh® THETA V) and the real-time recording of three authentic Secondary 4 (Grade 10) Liberal Studies lessons, in which a secondary education teacher\(^1\) harnessed the three mobile learning platforms to support classroom teaching and learning activities. In the course of recording, the camera (mounted on a tripod) was placed in the centre of the classroom (with 27 Grade 10 students); all the teaching and learning proceedings were documented in a 360-degree fashion. Liberal Studies was chosen as the contextual backdrop of the SV-IVR clips because this subject has been a compulsory course in Hong Kong senior secondary education since 2009. According to the course enrolment data for the 4 study cohorts, the majority (95.21\%) of the study participants completed their secondary education in Hong Kong; thus, they were able to interpret both the context and content of the SV-IVR clips. The 4.79\% of the participants who did not pursue their secondary education in Hong Kong were excluded from the data analysis in this study.

**Data collection procedures and instruments**

The same data collection procedures were implemented in the TLT course for all 4 cohorts, and the course was taught by the same instructor (an experienced lecturer with expertise in educational technology, knowledge of FC, and 10 years of teaching experience in the university). The following procedures were followed for each cohort:

1. Three weeks before Lecture X, the participants signed and returned consent forms consenting to participate in the research.
2. During the last 20 min of Lecture X-1 (i.e., the lecture before Lecture X), the participants were instructed on how to access a trial SV-IVR clip using their mobile phones and the provided cardboard goggles; the content of the trial SV-IVR (natural landscape of a wetland park in Hong Kong) was unrelated to the content of Lectures X, Y, and Z.
3. The aforementioned research manipulation was implemented in Weeks X, Y, and Z.
4. Directly after Lecture Z, the participants received an email invitation to complete the IMMS questionnaire (online) posted on the course LMS within 1 week.
5. One week after Lecture Z, 3 participants respectively majoring in language education, social and humanities education, and mathematics and science education were randomly selected and invited to attend a 90-minute semi-structured group interview.

The IMMS questionnaire was composed of two parts. The first part gathered information on the participants’ teaching majors and if they (1) had completed senior secondary education in Hong Kong and (2) had learning experience with FC. The second part consisted of 20 ARCS items (see Appendix A) that were modified from Yang’s

\(^1\) This secondary education teacher has received a number of government-supported teaching awards related to the educational use of technologies.
(2017) work. Each ARCS construct had five items for gauging the participants’ perceived motivational affordances of SV-IVR in supporting their pre-lecture learning during the research manipulation. The modifications were based on the aim and setting of this study. When responding to each item, the participants were deliberately asked to compare their pre-lecture individual learning experience in this study with their previous FC experience. The first modified version of the questionnaire was further revised according to the comments of the review panel. Further, 8 non-participating postgraduate education students from another local university were invited to cross-review the wording of each item to ensure that all items were generally understandable for pre-service teachers. In the final version of the questionnaire, the order of the 20 items was randomised, with each item scored using a 5-point Likert scale (i.e., 1 = Strongly Disagree, 5 = Strongly Agree).

The purpose of the semi-structured group interviews (under the same interview protocol) was to supplement the quantitative IMMS results. In the interviews, the interviewees were asked to comment on their pre-lecture individual learning experience during the research manipulation by comparing it with their previous FC experience. Appendix B presents the interview protocol; 4 questions, each corresponding to an ARCS construct, were posed. The interview data were processed using Crewell’s (2019) theme identification technique for layering qualitative transcripts with respect to the 4 constructs.

**Results**

A total of 176 completed questionnaires were received across the 4 cohorts (response rate: 93.62%). Five of them were excluded from the data analysis because those participants indicated that they did not pursue senior secondary education in Hong Kong. The remaining 171 participants all declared that they had previous FC learning experience. Also, the LMS logs indicated that all of them accessed the 3 sets of instructional materials during the 3-week research manipulation. Table 1 details the distribution of the participants (n=171) with respect to their teaching majors.

The overall reliability estimate (Cronbach’s α) of the 20 ARCS items was 0.89; the individual estimates of the 4 ARCS constructs were between 0.78 and 0.87 (see Table 2). The item-total correlations of the 20 items corresponding to the 4 constructs were between 0.71 and 0.87 (see Table 2), indicating that the reliability of the data was satisfactory. Furthermore, the confirmatory factor analysis (CFA: CFI=0.937, TLI=0.925; GFI=0.918, RMR=0.072 and SRMR=0.061) (Hu & Bentler, 1999) demonstrated that each item remained within the originally assigned construct (see Table 3).

Table 4 lists the descriptive statistics of the 4 ARCS constructs. The construct means ranged from 2.98 to 4.20 (out of 5). A one-way within-subjects ANOVA
revealed statistically significant differences among the 4 means \( F(3, 168) = 19.84, p < 0.001 \). Assessed using post-hoc paired samples t-tests, the mean of Confidence was significantly lower than that of Attention \( (p < 0.001) \), Relevance \( (p < 0.001) \), and Satisfaction \( (p < 0.001) \); no significant differences were noted among the means of Attention, Relevance, and Satisfaction. A MANOVA conducted on the linear combination of the 4 ARCS constructs showed no significant difference among the 3 teaching-major groups. Therefore, the evidence did not indicate that the participants’ teaching majors influenced their responses to the 20 ARCS items.

The quantitative analyses revealed that the participants across the 3 teaching majors significantly perceived that SV-IVR had desirable motivational affordances in supporting their pre-lecture individual learning in terms of Attention, Relevance, and Satisfaction, but not Confidence. In the semi-structured group interviews conducted in the 4 cohorts, the 12 participants (3 in each cohort), namely L1, L2, L3, and L4

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**Table 2** Reliability estimates of the ARCS constructs and items

| Item | Attention \( (\alpha = 0.85) \) | Item | Relevance \( (\alpha = 0.87) \) | Item | Confidence \( (\alpha = 0.78) \) | Item | Satisfaction \( (\alpha = 0.79) \) |
|------|-------------------------------|------|-------------------------------|------|-------------------------------|------|-------------------------------|
| Item | Item-total Correlation | Item | Item-total Correlation | Item | Item-total Correlation | Item | Item-total Correlation |
| a    | 0.80                         | f    | 0.80                         | k    | 0.73                         | p    | 0.78                         |
| b    | 0.81                         | g    | 0.82                         | l    | 0.72                         | q    | 0.73                         |
| c    | 0.78                         | h    | 0.79                         | m    | 0.78                         | r    | 0.71                         |
| d    | 0.83                         | i    | 0.81                         | n    | 0.71                         | s    | 0.72                         |
| e    | 0.74                         | j    | 0.87                         | o    | 0.75                         | t    | 0.79                         |

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**Table 3** Factor loadings of the ARCS constructs and items

| Item | Attention | Relevance | Confidence | Satisfaction |
|------|-----------|-----------|------------|--------------|
| a    | 0.80      |           |            |              |
| b    | 0.79      |           |            |              |
| c    | 0.75      |           |            |              |
| d    | 0.82      |           |            |              |
| e    | 0.76      |           |            |              |
| f    | 0.81      |           |            |              |
| g    | 0.80      |           |            |              |
| h    | 0.79      |           |            |              |
| i    | 0.80      |           |            |              |
| j    | 0.79      |           |            |              |
| k    |           | 0.70      |            |              |
| l    |           | 0.71      |            |              |
| m    |           | 0.73      |            |              |
| n    |           | 0.69      |            |              |
| o    |           | 0.73      |            |              |
| p    |           |           | 0.75      |              |
| q    |           |           | 0.77      |              |
| r    |           |           | 0.70      |              |
| s    |           |           | 0.72      |              |
| t    |           |           | 0.75      |              |
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Table 4 Descriptive statistics of the ARCS constructs

| Construct | Mean | Standard deviation |
|-----------|------|-------------------|
| Attention | 4.17 | 0.99              |
| Relevance | 4.20 | 1.18              |
| Confidence| 2.98 | 1.27              |
| Satisfaction | 4.08 | 1.07               |

(majoring in language education), SH1, SH2, SH3, and SH4 (majoring in social and humanities education), and MS1, MS2, MS3, and MS4 (majoring in mathematics and science education) shared their pre-learning experience pertaining to the ARCS motivational affordances of SV-IVR. Table 5 shows the relevant interview excerpts, which are later discussed in-depth.

Discussion and implications

The results of the study demonstrated that the participants across the 3 teaching majors positively perceived SV-IVR as having desirable motivational affordances in terms of Attention, Relevance, and Satisfaction, but not Confidence. Attention in Keller’s (2010) instructional motivation theory refers to drawing learners’ attention and arousing their interest in the instructional process. Thus, promoting learners’ curiosity and their active participation is crucial for engaging them in the course of learning (Cordova et al., 1996; Ryan et al., 2000). As evidenced in this research, unlike passively watching normal videos, when completing the pre-lecture individual learning tasks in FC, the participants actively explored the content of SV-IVR from their own interested points of view (see the excerpts of L1, L3, SH2, and MS1 in Table 5 under the Attention construct). In the pre-learning process, the participants were afforded with a large degree of freedom in terms of observing the authentic settings of mobile learning implementation, which effectively stimulated their curiosity about the pedagogical scenarios covered in the SV-IVR clips (see the excerpts of SH3, SH4, MS2, and MS4 in Table 5 under the Attention construct). One of the core strengths of SV-IVR is its ability to seamlessly capture the complexity of real-world situations (Kosko et al., 2021). Different from normal videos in which the “keyhole” effect usually limits the contextual complexity and richness of the real world (Roche et al., 2021), SV-IVR offers pre-service teachers the opportunity to holistically probe the happenings within the classroom without adhering to a single, pre-determined filming angle.

Relevance in Keller’s (2010) instructional motivation theory pertains to equipping learners with relevant information/knowledge that is aligned with their personal goals in the instructional process. This motivational construct echoes the theoretical conception of constructivism (Bruner, 1986; Vygotsky, 1978), which suggests that learners are more engaged in the course of learning when they are (1) situated in a real-life environment pertaining to the learning content, and (2) able to recognise that the learning outcomes are meaningful to their future endeavours. As evidenced in this research, through the SV-IVR-supported pre-lecture individual learning process in FC, the participants realised and appreciated their virtual immersion in an environment in which they would practice their teaching skills prior to beginning their teach-
When viewing the SV-IVR clips, I oriented my head frequently. I was excited about seeing different students’ responses corresponding to the teacher’s pedagogical actions in the classroom. (L1)

Different from normal videos [used in FC] that usually focus on filming how teachers teach. This time, I could clearly observe how the students participated in classroom activities in SV-IVR. (L3)

The pre-learning experience in SV-IVR was quite learner-centred. I could freely observe the classroom activities in relation to my own interests and points of view. This made me more engaged when conducting the required pre-lecture tasks before the corresponding lectures. (SH2)

The SV-IVR clips seamlessly documented all happenings in the classroom. It was so surprising to see such large individual differences among the students in the classroom. Immersed in SV-IVR, I could easily tell who was paying attention to the teacher and who was not. (SH3)

The immersive feature of SV-IVR made me more attentive to the subtle details of the teacher’s timely adjustments to his teaching strategies in response to the students’ unexpected behaviour in the classroom. (SH4)

I watched each SV-IVR clip at least 3 times. The first time I quickly browsed the general happenings in the classroom. The second time I focused on observing how the teacher taught. The last time I mainly focused on how the students learned. (MS1)

Being situated in SV-IVR stimulated my curiosity about the pedagogical implications of the interactions between the teacher and students in the classroom. I discussed my thoughts with my classmates during the in-lecture peer learning activities. (MS2)

Unlike the pre-learning tasks that I had experienced in other FC settings, with SV-IVR, I could contextually explore the classroom from different angles instead of following a single, pre-determined angle. (MS4)

When viewing the SV-IVR clips, I felt like I was situated in a real classroom, like where I am going to do my teaching practicum in the coming semester. (L2)

The observational tasks in SV-IVR, which really helped me remember the teacher’s pedagogical actions in the classroom scenarios, better enabled me to participate in the in-lecture discussions with my classmates. (L3)

SV-IVR made me feel like I was physically present in that classroom as one of the students. (L4)

SV-IVR richly captured the authentic complexity of the classroom from the perspectives of both teaching and learning. (SH1)

SV-IVR is a powerful tool that transported us into an authentic classroom without disturbing the normal teaching and learning exercises of the teacher and students. (SH2)

The immersive learning experience in SV-IVR assisted me in reducing the gap between my theoretical and practical knowledge. (SH4)

The observational tasks in SV-IVR offered me useful and practical tips on how to apply mobile learning platforms in a real classroom. (MS2)

Immersed in SV-IVR, I could preliminarily connect to the place where I will work in the near future. [The experience] inspired me to think up some practical problems related to classroom teaching that I could further discuss with my classmates and seek advice from the course instructor during the in-lecture time. (MS3)
### Table 5 (continued)

| Construct | Excerpts |
|-----------|----------|
| Confidence | • Compared with normal videos used in the pre-lecture stage of FC, accessing SV-IVR is less convenient. I can view normal videos anywhere and anytime, for example, on a bus or even in bed. But it would be so embarrassing to view SV-IVR in public places. Just imagine, I would look silly wearing cardboard goggles and continually moving my head on a bus or in the library, right? I had to complete all the pre-lecture tasks at home. (L1)  
  • To be honest, I was not totally comfortable wearing the cardboard goggles when doing the pre-learning tasks. It was my first time using this tool for learning. I felt a bit dizzy when viewing the SV-IVR clips for over around 10 min. (L2)  
  • I had to move my head frequently when viewing the SV-IVR clips. I had some physical discomfort, such as dizziness. (L4)  
  • When viewing the SV-IVR clips, it was impossible for me to pause or rewind the clips immediately. Also, it was inconvenient to re-access a specific point in the clips. (SH3)  
  • I am not a ‘tech-savvy’ person. It was my first time using SV-IVR. Compared with my classmates, I needed more time to familiarise myself with the operation of the SV-IVR clips using my mobile phone and the provided cardboard goggles. When doing the pre-lecture individual learning at home, I was worried that I was not competent enough to complete the required tasks. (SH4)  
  • I like playing 3-D IVR games. Honestly, I do not think cardboard goggles are a desirable HMD for viewing VR-based materials. This sacrifices the interactivities between users and the virtual world. I am used to using my high-quality HMD when playing IVR games. (MS1)  
  • When viewing the SV-IVR clips with my cardboard goggles, it was impossible to make my own learning notes, such as jotting down some important observations or screen-capturing, at the same time. (MS3)  
  • Compared with 3-D IVR games, I think a big drawback of SV-IVR is that it cannot provide users with interactive experiences. When doing the pre-learning tasks, I could not interact with the content; for example, I could not zoom in where I wanted to explore more details. (MS4) |
| Satisfaction | • Instead of being a passive observer in normal videos, this time, I could actively explore the pedagogical scenarios in SV-IVR in the pre-lecture stage of FC. (L1)  
  • SV-IVR made me become more engaged in observing classroom phenomena in the pre-lecture stage of FC and, in turn, increased my engagement in participating in the in-lecture stage of FC. (L2)  
  • It was a profound and rewarding experience for me as a pre-service teacher to participate in this SV-IVR-supported FC study. If possible, I would also like to try to use SV-IVR during my teaching practicum to facilitate immersive learning for my students. (L4)  
  • The use of SV-IVR over these weeks was so inspiring. In my upcoming teaching practicum, I will also use SV-IVR to record my lessons. The recorded lessons will be valuable sources for me to reflect on how to improve or enhance my teaching skills. (SH1)  
  • Our observations in SV-IVR effectively prepared my classmates and I for participating in the in-lecture peer learning activities. (SH3)  
  • I watched every SV-IVR clip at least 3 times. Although I spent more time on pre-lecture preparation in these weeks, it was worth it. If I adopt FC in my upcoming teaching practicum, I also want to use SV-IVR to support the pre-lesson learning part of my classes. (MS1)  
  • My classmates and I came up with many interesting questions related to the classroom phenomena for discussions during the lectures. All these questions stemmed from our observations in SV-IVR. (MS3)  
  • Different classmates had different points of view from watching the SV-IVR clips. All these interesting observations unfolded in the face-to-face lectures, generating fruitful discussions and interactions. (MS4) |
ing careers (see the excerpts of L2, L4, SH2, and MS3 in Table 5 under the Relevance construct). Moreover, the immersive pre-learning tasks situated them in the authentic classroom contexts, encouraging them to observe different real-life problems and issues related to classroom-based mobile learning from different perspectives. All these problems inspired lively discussions among the peers in the in-lecture stage of FC (see the excerpts of L3, SH1, SH4, and MS2 Table 5 under the Relevance construct). Immersion is one of the most key attributes that SV-IVR inherits from IVR (Geng et al., 2021; Kavanagh et al., 2016; Shadiev et al., 2021; Ulrich et al., 2021; Jong et al., 2020). Normal videos can never provide pre-service teachers with such immersive experiences when conducting remote classroom observations.

Confidence in Keller’s (2010) instructional motivation theory refers to establishing learners’ positive expectations towards believing their ability to achieve the learning success in the instructional process. Learning motivation is reinforced when learners are self-possessed that they are able to successfully reach the expected learning goals in the course of learning (Dong et al., 2020; Martin et al., 2014; Mayer, 2019). As demonstrated in this research, however, the use of SV-IVR had some intrinsic hindrances affecting the participants’ confidence in accomplishing the pre-lecture individual learning tasks in FC. For example, when viewing the SV-IVR clips, some participants experienced unpleasant sensations or physical discomforts (see the excerpts of L2 and L4 in Table 5 in the Confidence construct). This finding echoes other reports about the disadvantages of adopting IVR, if not SV-IVR, in education (Fromm et al., 2021; Shadiev et al., 2021). Additionally, some participants expressed concerns about the convenience and user-friendliness of SI-IVR compared with normal videos which can be easily accessed anytime and anywhere using a mobile phone and easily controlled (e.g., play, pause, stop and rewind functions) using a software media player. These participants stated that the reduced convenience and user-friendliness of SV-IVR hindered some of their conventional study practices employed in the individual learning process, such as note-taking and screen-capturing (see the excerpts of L1, SH3, and MS3 in Table 5 under the Confidence construct). Furthermore, not all participants were “digital natives” (Prensky, 2016) capable of quickly familiarising themselves with new technologies without difficulty (Jong 2019); some participants worried about their competency for completing the SV-IVR-based pre-learning tasks (see the excerpt of SH4 in Table 5 under the Confidence construct). Some tech-savvy participants mentioned that, instead of harnessing computer-generated imagery IVR and sophisticated HMDs, employing SV-IVR and low-cost cardboard goggles sacrificed the quality of users’ immersive experience and possible interactivities between users and the virtual world in the pre-learning process (see the excerpt of MS1 and MS 4 in Table 5 in the Confidence construct). These weaknesses of using SV-IVR to support the pre-lecture stage of FC in pre-service teacher education need to be addressed by further research efforts.

Satisfaction in Keller’s (2010) instructional motivation theory refers to learners’ feelings of satisfaction and gratification in the instructional process. Learners’ motivation in completing a learning task closely correlates with how satisfied they are with the balance between the efforts expended and rewards obtained in the course of learning (Chiu et al., 2020; Dong et al., 2020; Plass et al., 2020). As evidenced in this research, the participants positively reported “no longer being a passive learner,”
“being highly engaged in immersive SV-IVR,” “repeatedly viewing the SV-IVR clips,” and “enjoying fruitful in-lecture discussions and interactions;” all of these reports of satisfaction stemmed from their successful completion of the pre-lecture individual tasks in FC (see the excerpts of L1, L2, SH3, MS1, MS3, and MS4 in Table 5 under the Satisfaction construct). Furthermore, because of the satisfying and rewarding experience provided through SV-IVR in this study, some participants planned to adopt this technological tool to support the implementation of immersive learning and FC in the coming teaching practicums and to facilitate self-reflection to improve their teaching skills (see the excerpts of L4, SH1, and MS1 in Table 5 under the Satisfaction construct). In fact, pre-service teachers usually adopt or adapt useful teaching and learning approaches and tools encountered in their pre-service training and teaching internships in their professional teaching practice (Jong et al., 2021; Roche et al., 2021).

The strengths and weaknesses of harnessing SV-IVR in FC revealed in this study offer the field a number of avenues for future research. Regarding the strengths, SV-IVR can be a pragmatic tool to develop “virtual school attachment” through situating and immersing education students in authentic early-childhood and K-12 schooling environments on an on-demand basis. This is particularly useful in the context of the Covid-19 pandemic, during which the physical access to schools has been inconvenient, difficult, or sometimes impossible because of various social-distancing or lockdown measures. Moreover, education students can also make use of an SV-IVR camera to seamlessly record the micro-teaching exercises conducted during pre-service teacher training and the real face-to-face lessons taught during their teaching practicums. Recorded clips can then be used for conducting post-teaching re-situated self-reflection or discussed in peer learning activities for collective teaching improvement. In terms of the weaknesses of SV-IVR, researchers should further explore how to address the problems of its lack of interactivities and user-unfriendliness. Recently, aimed at making SV-IVR more interactive and access-friendly, some K-12 studies (with positive learning results, though not in FC settings) have endeavoured to create so-called “hyper SV-IVR” that can embed, for example, quizzes, zoomable images, audio memos for note-taking, and head-movement-controlled buttons for play, pause, stop, and rewind functions by using an open SV-IVR development platform called EduVenture-VR (https://vr.ev-cuhk.net/) (e.g., Chang et al., 2020; Chen et al., 2021; Chien et al., 2021; Geng et al., 2021; Jong et al., 2020). It is worth looking into the possibility of introducing “hyper SV-IVR” to support the pre-lecture stage of FC in pre-service teacher education.

When introducing the use of SV-IVR to pre-service teacher education or higher education in general, we cannot simply assume that all students will be capable of quickly familiarising themselves with the use of this technological tool. As evidenced in this research, the “non-tech-savvy” participants needed more time, if not more technical guidance and assistance, in order to get prepared for participating in SV-IVR-supported learning. As for the issue of sensory or physical discomforts caused by the use SV-IVR and cardboard goggles, the field has to develop guidelines and further directions for SV-IVR developers, course instructors and learners regarding the educational use of this technological tool, such as (1) appropriate length (duration) of an SV-IVR clip for teaching and learning purpose in general, (2) cautions
and reminders of potential discomforts that users may experience when watching SV-IVR with HMDs, and (3) alternative modes of access to SV-IVR without the use of HMDs, for example, using touch-screen finger sliding actions or gyroscope-supported body angular movements, instead of using head movements, to navigate SV-IVR clips on mobile phones.

**Limitations**

The participants in this research were education students (pre-service teachers) who intended to pursue teaching careers. Compared with other university students, these participants might be more interested in FC and the educational use of SV-IVR, because they may adopt and adapt such pedagogical approaches and tools that they become familiar with in pre-service training for their teaching practicums or professional teaching (Jong et al., 2021; Kosko et al., 2021). Similar to other FC researchers, educators and in-service teachers, the participants might also be eager to learn the motivational affordances of SV-IVR in support of the outside-the-classroom stage of FC, which might have engendered their high engagement in this research. Thus, the results of this study might not be directly applicable to other FC contexts for other higher education disciplines. The Hawthorne effect, the tendency of people to work more diligently and perform more successfully when they are acting as research participants (McBride, 2019), is another potential challenge to this work. If the participants had not been involved in this research, perhaps the participants of this study would not have perceived SV-IVR as having the same intensity of effect on supporting pre-lecture individual learning in FC (in terms of ARCS). Therefore, further investigation into the sustainability and changes of the perceived affordances among these education students is required when analysing SV-IVR-supported pre-learning in relation to other topics or courses in their pre-service teacher training.

Although this research elucidated the motivational affordances of SV-IVR’s Attention, Relevance, and Satisfaction constructs in supporting the pre-lecture stage of FC education, SV-IVR may not be suitable for creating all types of self-accessed instructional materials in FC-based individual learning. From the pedagogical perspective, in the context of pre-service teacher education, the situation and immersion of education students in an authentic classroom for observation-based pre-lecture learning is well justified to prepare them to participate in in-lecture peer learning in FC. However, for other FC settings where the situation and immersion are not critical pedagogical elements of the pre-learning tasks (such as equipping learners with preliminary mathematics knowledge in a flipped mathematics class [Lo et al., 2021] or preliminary syntactic knowledge in a flipped programming class [Yildiz Durak 2018]), normal videos may already, or more effectively, serve for the outside-the-classroom stage of FC.
Conclusions

For as long as FC has been a buzzword in higher education, one of the prominent obstacles of this “blended” instructional approach has been learners’ lack of motivation to complete assigned pre-lecture individual learning tasks prior to participating in the in-lecture peer learning activities (e.g., Bai et al., 2020; Howitt et al., 2015; Lee et al., 2019; Jong 2019b). Alternative methods and media with greater motivational power to support the outside-the-classroom stage of FC must be explored. Grounded in Keller’s (1999, 2008, 2010) instructional motivation theory, this study probed the ARCS motivational affordances of SV-IVR in supporting the pre-lecture individual learning process in the context of pre-service teacher education. The research results indicated that the participating pre-service teachers across teaching majors (language education, social and humanities education, and mathematics and science education) positively perceived SV-IVR as having desirable motivational affordances in terms of Attention, Relevance, and Satisfaction but not Confidence.

The contributions of this study are fourfold. First, it revealed the motivational affordances of SV-IVR in supporting the outside-the-classroom stage of FC. Second, the research results offer researchers and educators both scholarly and practical insights into the adoption of SV-IVR in pre-service teacher education. Third, a modified and validated IMMS instrument was developed for measuring pre-service teachers’ perceptions of the motivational affordances of SV-IVR in terms of the four ARCS constructs, which can be applied in future research in the field. Finally, this work sheds light on a number of avenues for further investigation into the use of SV-IVR in pre-service teacher education and opens up new research opportunities for leveraging this technological tool in supporting FC-based teaching and learning in other non-teacher-education disciplines where the pedagogical approaches of situated and immersive learning are frequently adopted, such as in social work, nursing, and construction management, natural science and geology education, to name a few.

Appendix A: 20 ARCS items

Compared with your previous pre-lecture individual learning experience in flipped classroom (FC), please evaluate the following statements concerning the SV-IVR-based pre-learning activities that you have experienced in this study on a 5-point Likert scale.
Flipped classroom: motivational affordances of spherical video-based...

| Construct | Item |
|-----------|------|
|           | Strongly Disagree: 1 | Disagree: 2 | Neutral: 3 | Agree: 4 | Strongly Agree: 5 |
| **Attention** | Compared with my previous pre-lecture individual learning experience in FC: a. SV-IVR helps me stay more focused in the pre-learning process. b. I have more feelings of surprise when completing the observational tasks in SV-IVR. c. SV-IVR is more visually engaging than the self-accessed instructional materials that I previously used. d. SV-IVR stimulates my curiosity more during the pre-learning tasks. e. I maintain concentration more effectively when completing the observational tasks in SV-IVR. |
| **Relevance** | Compared with my previous pre-lecture individual learning experience in FC: f. I can quote more relevant examples based on my observations in SV-IVR when participating in the in-lecture peer learning activities. g. SV-IVR more authentically captures the pedagogical context of classroom teaching and learning. h. The observational tasks in SV-IVR help me interpret the teacher’s role in the pedagogical scenarios more effectively. i. I gain a clearer picture of students’ learning behaviour when completing the observational tasks in SV-IVR. j. It is easier for me to draw connections between my observations in SV-IVR and my future teaching environment. |
| **Confidence** | Compared with my previous pre-lecture individual learning experience in FC: k. SV-IVR increases my confidence more when I am completing the observational tasks in the pre-learning process. l. I am able to finish the required pre-learning tasks without much difficulty. m. The use of SV-IVR makes the pre-learning goals seem more achievable. n. I can complete the observational tasks more competently in SV-IVR. o. It is easier for me to successfully complete the pre-learning tasks in SV-IVR. |
| **Satisfaction** | Compared with my previous pre-lecture individual learning experience in FC: p. I recognise the value of using SV-IVR to support the pre-learning process. q. The observations in SV-IVR prepare me more effectively for participating in the in-lecture peer learning activities. r. Completing the observational tasks in SV-IVR gives me a greater sense of accomplishment. s. It is an inspiring experience for me, as a pre-service teacher, to participate in the SV-IVR-supported pre-learning process. t. I feel more rewarded for my efforts after completing the pre-learning tasks in SV-IVR. |

Appendix B: Semi-structured group interview protocol

Compared with your previous pre-lecture individual learning experiences in flipped classroom (FC), please comment on the following:

1. Attention: How effectively could SV-IVR capture your interest, stimulate your thinking, and retain your attention in the pre-learning process? Why?
2. Relevance: How effectively could SV-IVR address your learning needs as a pre-service teacher and offer you authentic learning experience in the pre-learning process? Why?
3. Confidence: How effectively could SV-IVR make you feel confidence that the expected learning goals of the pre-learning tasks were achievable? Why?

4. Satisfaction: How effectively could SV-IVR induce your positive feelings of satisfaction and achievement after you had completed the pre-learning tasks? Why?

Declarations

Conflict of interest The authors declare no conflict of interest.

References

Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. Computers & Education, 126, 334–345

Alexander, B., Ashford-Rowe, K., Barajas-Murphy, N., Dobbin, G., Knott, J., McCormack, M., Pomerantz, J., Seilhamer, R., & Weber, N. (2019). EDUCAUSE horizon report 2019. EDUCAUSE

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J., & Wittrock, M. C. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Pearson

Bai, S., Hew, K. F., & Huang, B. (2020). Does gamification improve student learning outcome? Evidence from a meta-analysis and synthesis of qualitative data in educational contexts. Educational Research Review, 30, 100322

Bergmann, J., & Sams, A. (2015). Flipped learning for social studies instruction. International Society for Technology in Education

Bond, M. (2020). Facilitating student engagement through the flipped learning approach in K-12: A systematic review. Computers & Education, 151, 103819

Bower, M., DeWitt, D., & Lai, J. W. M. (2020). Reasons associated with preservice teachers’ intention to use immersive virtual reality in education. British Journal of Educational Technology, 51(6), 2214–2232

Bower, M., & Jong, M. S. Y. (2020). Immersive virtual reality in education. British Journal of Educational Technology, 51(6), 1981–1990

Bruner, J. S. (1986). Actual minds, possible worlds. Cambridge: Harvard University Press

Chang, S. C., Hsu, T. C., Kuo, W. C., & Jong, M. S. Y. (2020). Effects of applying a VR-based two-tier test strategy to promote elementary students’ learning performance in a Geology class. British Journal of Educational Technology, 51(1), 148–165

Chen, M. Y., Chai, C. S., Jong, M. S. Y., & Jiang, M. Y. C. (2021). Teachers’ conceptions of teaching Chinese descriptive composition with interactive spherical video-based virtual reality. Frontiers in Psychology, 12, 591708

Cheng, L., Ritzhaupt, A. D., & Antonenko, P. (2019). Effects of the flipped classroom instructional strategy on students’ learning outcomes: A meta-analysis. Educational Technology Research and Development, 67(4), 793–824

Chien, S. Y., Hwang, G. J., & Jong, M. S. Y. (2020). Effects of peer assessment within the context of spherical video-based virtual reality on EFL students’ English-Speaking performance and learning perceptions. Computers & Education, 146, 103751

Chiu, T. K. F., Jong, M. S. Y., & Mok, I. A. C. (2020). Does learner expertise matter when designing emotional multimedia for learners of primary school mathematics? Educational Technology Research & Development, 68, 2305–2320

Cordova, D. I., & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. Journal of Educational Psychology, 88(4), 715–730

Creswell, J. W. (2019). Educational research: Planning, conducting, and evaluating quantitative and qualitative research (6th ed.). Pearson Education

Daugherty, K. K. (2019). ARCS motivation model application in a pharmacy elective. Currents in Pharmacy Teaching and Learning, 11(12), 1274–1280
Dong, A. M., Jong, M. S. Y., & King, R. (2020). How does prior knowledge influence learning engagement? The mediating roles of cognitive load and help-seeking. *Frontiers in Psychology, 11*, 591203

Fox, W. H., & Docherty, P. D. (2019). Student perspectives of independent and collaborative learning in a flipped foundational engineering course. *Australasian Journal of Educational Technology, 35*(5), 79–94

Fromm, J., Radianti, J., Wehking, C., Stiegitz, S., Majchrzak, T. A., & vom Brocke, J. (2021). More than experience? On the unique opportunities of virtual reality to afford a holistic experiential learning cycle. *The Internet and Higher Education, 50*, 100804

Geng, J., Chai, C. S., Jong, M. S. Y., & Luk, E. T. H. (2021). Understanding the pedagogical potential of interactive spherical video-based virtual reality from the teachers’ perspective through the ACE framework. *Interactive Learning Environments, 29*(4), 618–633

Geng, J., Luk, E. T., & Jong, M. S. Y. (2017). Teachers’ concerns about adopting interactive spherical video-based virtual reality. In: *Proceedings of the 25th international conference on computers in education* (pp. 261–263). Asia-Pacific Society for Computers in Education

Higuera-Trujillo, J. L., Maldonado, J. L., & Millán, C. L. (2017). Psychological and physiological human responses to simulated and real environments: A comparison between photographs, 360° panoramas, and virtual reality. *Applied Ergonomics, 65*, 398–409

Howitt, C., & Pegrum, M. (2015). Implementing a flipped classroom approach in postgraduate education: An unexpected journey into pedagogical redesign. *Australasian Journal of Educational Technology, 31*(4), 458–469

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1–55

Huang, B., & Hew, K. F. (2018). Implementing a theory-driven gamification model in higher education flipped courses: Effects on out-of-class activity completion and quality of artifacts. *Computers & Education, 125*, 254–272

Hwang, G. J., Yin, C., & Chu, H. C. (2019). The era of flipped learning: Promoting active learning and higher order thinking with innovative flipped learning strategies and supporting systems. *Interactive Learning Environments, 27*(8), 991–994

Hwang, G. J., Lai, C., & Wang, S. (2015). Seamless flipped learning: A mobile technology-enhanced flipped classroom with effective learning strategies. *Journal of Computers in Education, 2*(4), 449–473

Innocenti, A. (2017). Virtual reality experiments in economics. *Journal of Behavioural and Experimental Economics, 69*, 71–77

Jiang, M. Y. C., Jong, M. S. Y., Lau, W. W. F., Chai, C. S., Liu, K. S. X., & Park, M. (2020). A scoping review on flipped classroom approach in language education: Challenges, implications and an interaction model. *Computer Assisted Language Learning*, [https://doi.org/10.1080/09588221.2020.1789171](https://doi.org/10.1080/09588221.2020.1789171)

Jiang, M. Y. C., Jong, M. S. Y., Lau, W. W. F., Chai, C. S., & Wu, N. (2021). Using automatic speech recognition technology to enhance EFL learners’ oral language complexity in a flipped classroom. *Australasian Journal of Educational Technology, 37*(2), 110–131

Jong, M. S. Y. (2017). Empowering students in the process of social inquiry learning through flipping the classroom. *Educational Technology & Society*, 20(1), 306–322.

Jong, M. S. Y., Chen, G. W., Tam, V., & Chai, C. S. (2019a). Adoption of flipped learning in social humanities education: The FIBER experience in secondary schools. *Interactive Learning Environments, 27*(8), 1222–1238.

Jong, M. S. Y. (2019). Sustaining the adoption of gamified outdoor social enquiry learning in high schools through addressing teachers’ emerging concerns: A three-year study. *British Journal of Educational Technology, 50*(3), 1275–1293

Jong, M. S. Y. (2019b). To flip or not to flip: Social science faculty members’ concerns about flipping the classroom. *Journal of Computing in Higher Education, 31*(2), 391–407.

Jong, M. S. Y., Tsai, C. C., Xie, H., & Wong, F. K. K. (2020). Integrating interactive learner-immersed video-based virtual reality into learning and teaching of physical geography. *British Journal of Educational Technology, 51*(6), 2063–2078.

Jong, M. S. Y. (2020). Promoting elementary pupils’ learning motivation in environmental education with mobile inquiry-oriented ambience-aware fieldwork. *International Journal of Environmental Research & Public Health, 17*(7), 2504.

Jong, M. S. Y., Song, Y., Sologway, E., & Norris, C. (2021). Teacher Professional Development in STEM Education. *Educational Technology & Society, 24*(4), 81–85
Jong, M. S. Y., Chen, G., Tam, V., Hue, M. T., & Chen, M. (2022). Design-based research on teacher facilitation in a pedagogic integration of flipped learning and social enquiry learning. Sustainability, 14, 996.

Kavanagh, S., Luxton-Reilly, A., Wünsche, B., & Beryl, B. (2016). Creating 360° educational video: A case study. Proceedings of the 28th Australian Conference on Computer-Human Interaction (pp. 34–39). ACM

Keller, J. M. (1999). Motivation in cyber learning environment. International Journal of Educational Technology, 1, 7–30

Keller, J. M. (2008). First principles of motivation to learn and e-learning. Distance Education, 28(2), 175–185

Keller, J. M. (2010). Motivational design for learning and performance: The ARCS model approach. Springer

Kosko, K. W., Ferdig, R. E., & Zolfaghari, M. (2021). Preservice teachers’ professional noticing when viewing standard and 360 video. Journal of Teacher education, 72(3), 284–297

Kurt, P. Y., & Keçik, İ. (2017). The effects of ARCS motivational model on student motivation to learn English. European Journal of Foreign Language Teaching, 2(1), 22–44

Lee, E. A. L., Wong, K. W., & Fung, C. C. (2010). How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach. Computers & Education, 55, 1424–1442

Lee, J., & Choi, H. (2019). Rethinking the flipped learning pre-class: Its influence on the success of flipped learning and related factors. British Journal of Educational Technology, 50(2), 934–945

Lin, H. C. S., Yu, S. J., Sun, J. C. Y., & Jong, M. S. Y. (2021). Engaging university students in a library guide through wearable spherical video-based virtual reality: Effects on situational interest and cognitive load. Interactive Learning Environments, 29(8), 1272–1287

Lin, V., Barrett, N. E., Liu, G. Z., Chen, N. S., & Jong, M. S. Y. (2021). Supporting dyadic learning of English for tourism purposes with scenery-based virtual reality. Computer Assisted Language Learning. doi: https://doi.org/10.1080/09588221.2021.1954663

Lo, C. K., & Hew, K. F. (2021). Developing a flipped learning approach to support student engagement: A design-based research of secondary school mathematics teaching. Journal of Computer Assisted Learning, 37(1), 142–157

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. Learning and Instruction, 60, 225–236

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. Cognitive Science, 5(4), 333–369

Martin, A. J., Yu, K., & Hau, K. T. (2014). Motivation and engagement in the ‘Asian century’: A comparison of Chinese students in Australia, Hong Kong, and Mainland China. Educational Psychology, 34(4), 417–439

Mayer, R. E. (2019). How to be a successful student: 20 study habits based on the science of learning. Routledge

McBride, D. M. (2019). The process of research in psychology (4th ed.). Sage

Moro, C., Stromberga, Z., & Stirling, A. (2017). Virtualisation devices for student learning: Comparison between desktop-based (Oculus Rift) and mobile-based (Gear VR) virtual reality in medical and health science education. Australasian Journal of Educational Technology, 33(6), 1–10

O’Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. Internet and Higher Education, 25, 85–95

Passig, D., Tzuriel, D., & Eshel-Kedmi, G. (2016). Improving children’s cognitive modifiability by dynamic assessment in 3D Immersive virtual reality environments. Computers & Education, 95, 296–308

Plass, J., Mayer, R. E., & Homer, B. (Eds.). (2020). Handbook of game-based learning. MIT Press

Prensky, M. (2016). Education to better their world: Unleashing the power of 21st-century kids. Teachers College Press

Roche, L., Kittel, A., Cunningham, I., & Rolland, C. (2021). 360° video integration in teacher education: A SWOT analysis. Frontiers in Education, 6, 761176

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology, 25(1), 54–67

Sato, S., & Kageto, M. (2018). The use of 360-degree movies to facilitate students’ reflection on learning experiences. Proceedings of the 4th International Symposium on Educational Technology (pp. 266–267). IEEE
Schunk, D. H., Meece, J. R., & Pintrich, P. R. (2008). Motivation in education: Theory, research, and applications (3rd ed.). Pearson

Shadiev, R., Yang, L., & Huang, L. Y. (2021). A review of research on 360-degree video and its applications to education. Journal of Research on Technology in Education. https://doi.org/10.1080/15391523.2021.1928572

Song, Y., Jong, M. S. Y., Chang, M., & Chen, W. (2017). “HOW” to design, implement and evaluate the flipped classroom? – A Synthesis. Educational Technology & Society, 20(1), 180–183

Southgate, E., Smith, S. P., Cividino, C., Saxby, S., Kilham, J., Ether, G., Scevak, J., Summerville, D., Buchanan, R., & Bergin, C. (2019). Embedding immersive virtual reality in classrooms: Ethical, organisational and educational lessons in bridging research and practice. International Journal of Child-Computer Interaction, 19, 19–29

Turel, Y. K., & Sanal, S. O. (2018). The effects of an ARCS based e-book on student’s achievement, motivation and anxiety. Computers & Education, 127, 130–140

Ulrich, F., Helms, N. H., Frandsen, U. P., & Rafin, A. V. (2021). Learning effectiveness of 360° video: experiences from a controlled experiment in healthcare education. Interactive Learning Environments, 29(1), 98–111

Vygotsky, L. (1978). Mind and society. Cambridge, MA: MIT Press

Wah, L. K. (2015). The effects of instruction using the arcs model and Geogebra on upper secondary students’ motivation and achievement in learning combined transformation. Asia Pacific Journal of Educators and Education, 30, 141–158

Wu, W. L., Hsu, Y., Yang, Q. F., Chen, J. J., & Jong, M. S. Y. (2021). Effects of the self-regulated strategy within the context of spherical video-based virtual reality on students’ learning performances in an art history class. Interactive Learning Environments. https://doi.org/10.1080/10494820.2021.1878231

Yang, M. (2017). Geography students’ motivation in a mobile VR-based class: A case study in a Hong Kong middle school [Master’s thesis]. The Chinese University of Hong Kong

Yildiz Durak, H. (2018). Flipped learning readiness in teaching programming in middle schools: Modeling its relation to various variables. Journal of Computer Assisted Learning, 34(6), 939–959

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