Title

Taking in the complete picture: framing the use of 360-degree video for teacher education practice and research

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Abstract

360-degree video combined with virtual reality has potential as a significant tool and field of study in teacher education. However, research to date has been fragmented and undertaken almost exclusively in high-income contexts. In response, we articulate key features of the emerging narrative that can be used to interrogate, define and guide the opportunities afforded by this technology to support improved teaching across the globe. Furthermore, we undertake a small pilot of the technology with educators in rural India as an innovative step to extend the evidence base to low-resource contexts.

Introduction

Observation is a commonplace activity in both teacher education and educational research, yet the options available for documenting and recording classroom practice have been limited due to the gaze and purpose of the physically present observer and, until now, the technical limitations of technology. Video affords teachers, teacher educators, and researchers alike a distinct ‘window into practice’ (Zhang et al., 2011, p.459) from which to engage, experience and reflect on teaching and learning in the classroom. However,

conventional video only partially opens this window, meaning the ambition of allowing an observer 'to *enter* the world of the classroom' (our italics) (Sherin, 2004, p.13) without having to be there remains limited.

360-degree video represents a new method for capturing, re-viewing, and analysing educational practice. Also referred to as spherical-based video virtual reality (SVVR) in the context of virtual reality (VR) use, this technology holds potential for improving teacher education and educational research (Cross et al., 2018; Theelen, 2019; Kosko et al., 2020). When watching 360-video with a VR headset, the viewer can look at and listen to different parts of the classroom while the video plays in real-time. Whether conceived as an evolution of existing practice or as a potential paradigm shift, these technologies open a new conceptual space for 360-degree video that is related to, but distinct from, existing strands of educational research associated with the use of conventional video in teacher professional development (Blomberg et al., 2014; Borko et al., 2010; Gaudin & Chaliès, 2015). Greater affordability and the ability to play clips on user-owned VR headsets heighten the need to foreground questions relating to how best to conceptualise and use 360-degree video for professional development and educational research in diverse contexts.

While 360-degree video and SVVR represent a very different proposition from that of conventional video, field-based research or theorisation of how such technologies might impact on teacher professional learning is only very recent (Theelen et al, 2020; Walshe & Driver, 2019; Kosko et al. 2020). Importantly, there is a strong disparity between the higher-income contexts in which most research of conventional and 360-degree video technologies in teacher education have taken place (Gaudin & Chaliès, 2015; Major & Watson, 2018, Seidel et al., 2011) and the low- and medium-income countries where large-scale improvements in teaching quality are most needed (UNESCO, 2017) and pupil achievement is low (World Bank, 2018). This absence of studies from the Global South may have been due to challenges posed by the bulky, fixed, and relatively expensive equipment needed, such as video cameras, and a lack of access to electricity in schools and teacher education institutes or colleges. But if, as previous research suggests, there is a critical need for teacher educators and educational researchers to develop and study best practice for this emerging technology (Kosko et al., 2020), it will be essential to expand work to include studies in low-resource contexts.

In many low- and medium income countries, policy advocates pedagogic change from a didactic model involving the transmission of knowledge (often labelled 'teacher-centred') to a 'learner-centred' approach (World Bank, 2018; Schweisfurth, 2011), but a series of studies and reports indicates that the latter approach is only rarely observed in school classrooms in the Global South (Akeampong, 2017; UNESCO, 2013). The nature of pre- and in-service teacher education offered to aspiring and practising teachers is central to most arguments and initiatives to improve teachers' classroom practice. Hence, a significant goal for achieving quality education for all children - in line with Sustainable Development Goal 4 (sdgs.un.org) - is delivering mediated, engaging, reflective and participatory teacher professional development (Popova et al., 2018) and helping teachers take ownership of this (Grossman et al., 2009). In previous work (Murphy & Wolfenden, 2013) we have outlined how this should engage teachers in enquiry of their own problems of practice and offer them opportunities to consider new ideas in line with the cultural and curricula contexts of their classrooms. With their ability to offer full immersion in the classroom, 360-degree video and VR technologies may have a role in supporting such pedagogic change by enhancing teachers' understandings of the interactions within their classrooms and hence their agency to effect change in their practice. These technologies are potentially well-suited to use in low-resource contexts as the key technological components are mobile and do not require mains electricity or the internet, and the central, most expensive element – the smartphone - may already be owned by the teacher (smartphone ownership in developing economies currently ranges from 24% in India to over 60% in Brazil and South Africa (Pew Research Centre, 2019)).

In response, we explore two key research questions in this paper: (1) How should we conceptualise the emerging evidence and narrative associated with the use of 360-degree video in teacher education in such a way that is useful in guiding practice and research? (2) How do the key dimensions of this conceptualisation resonate with teacher education practice in low-income contexts? The first question is addressed by an interrogation and articulation of the key composite dimensions of the emerging narrative around the use of 360-degree video for teacher education. The second by analysis of data from a pilot exploratory study that trialled the process of recording and then viewing teachers' classroom practice with 360-video and VR headsets in a low-resource, relatively remote setting. This field activity was designed to elicit views from three essential stakeholder groups: pre-service teachers, in-service teachers, and teacher educators and to ascertain the practical feasibility of using these technologies in such an environment. In this way, our

research aims to indicate the appropriateness or not of the narrative framework in a low-resource context with little prior history of video observation in teacher education. Research from low- and medium-income contexts at the outset can drive forward investigations into this emerging field of enquiry rather than remaining peripheral to it.

Our approach

We focused our literature searches on three inter-connected areas: use of 360-degree video in teacher training and teacher professional development, use of conventional video in teacher training and professional development, and general scholarship on teacher skills such as observation, perception and noticing. We focused on teacher professional development so excluded use of the technology by teachers in school classrooms for the support of pupil learning although we do consider this later in the discussion. Working iteratively, we distilled the themes and components identified into four constituent dimensions: opening observation; critical distance; social presence; and investigative space. Each dimension describes a key affordance. The juxtaposition of these four (Figure 1) provides a conceptual articulation of the emerging narrative from which to frame, unpack and think through the application of 360-degree video in teacher education.

[FIG_1.JPG]

Figure 1. Key dimensions to the perceived affordances of 360-degree video and VR in teacher education

For clarity, this paper uses the term ‘conventional’ to refer to video shot with a standard single lens pointing in one direction (i.e. at the subject being filmed), whilst 360-degree video is that created by recording using omnidirectional cameras comprising multiple lenses fixed to the same camera or camera rig, pointing in diametrically opposite directions. When watching 360-degree video with a VR headset (a spherical video-based virtual reality), the viewer can turn, look, and listen in any direction while the video plays in real-time. Some VR headsets are integrated units that are standalone or require connection to a computer while others, like those used in this pilot (Samsung Gear), operate by plugging a smartphone into the front of the viewer. When watching 360-degree video on a VR headset, the viewer is not engaging in computer-generated VR

content (Lee et al., 2017) but in a virtualised reality of pre-recorded digital video or photographs of 'actual' places. The creation of 360-degree video can be cheaper and quicker as it does not require the high overheads associated with development of VR (Geng et al, 2020).

Conceptual framings for 360-degree video in teacher education

Opening observation

Using conventional video for classroom observation has been found to help teachers develop skills in reflection and self-analysis, build confidence and emotional preparation, capture evidence of improved practice, witness and discuss alternative ways of teaching to their own, challenge their pedagogic assumptions, and connect learning theory with classroom experiences (Blomberg et al., 2014; Tripp & Rich, 2012). Conventional video has also appealed to educators seeking ever more authentic 'access' to classroom events, as a means of enabling classroom reform and the creation of effective mediating artefacts (Gaudin & Chaliès, 2015, p.42-43). Video also can negate the need for a classroom observer to be physically present, which can reduce disruption to the teacher and learners (Liang, 2015)

Prior to 360-degree video, a number of studies investigated ways of using conventional video cameras to broaden and enrich the observational gaze. Researchers developed remote observation systems whereby teacher educators remotely controlled motorised cameras in a classroom from a separate teaching room in which they discussed the live feed with trainee teachers (Lee & King, 1966; Dyke, Harding & Liddon, 2008; Wang & Wiesemes, 2012; Marsh, Mitchell & Adamczyk, 2010), used two cameras (Snoeyink, 2010), or asked teachers to wear head-mounted cameras (Estapa & Amador, 2016). Yet, in all such implementations, a central problem remains: when (re)watching conventional video, the viewer has little control over what, or more specifically where, they focus on in the classroom because the decision has already been taken at the recording stage.

360-degree video lends itself well to improving the quality and frequency of these lesson observations and the opening up of classrooms to peers, teacher educators, mentors, assessors and researchers. We consider 360-degree video can both challenge and blur the long-held distinction drawn between live classroom observation and the video recording of classroom activity. Previously, this distinction has been a major

barrier to the practice of lesson observation, with Sherin (2004) noting that 'as an observer or teacher, you [must] decide what deserves attention and you might decide to pay attention to multiple aspects of classroom interactions at once' while, in contrast, the conventional video camera 'looks in only one direction at a time … [with] no opportunity to turn your head to look around and see what else is going on in the classroom.' With 360-degree, such choices about where to look need not be taken at the time of recording and a recording can be re-watched with a different focus each time. We propose using the term 'luxury of frame' to refer to this unique affordance. It helps to emphasise how the 360-degree video format places no limits as to which direction – which framing of the classroom – the viewer sees. While viewers of conventional video benefit from watching video *when*ever they choose – a luxury of time – viewers of 360-degree video also benefit from the luxury of watching *what*ever they choose. 360-degree video can therefore overcome some of the criticisms of conventional video related to framing, controlling and limiting the viewer's gaze.

While conventional video may be seen as a means of 'opening classroom doors' (Zhang et al., 2011), we suggest 360-degree video offers a more convincing case for removing the need for a physically present observer, because it places no limits as to which direction – which framing of the classroom – the viewer can see. The observer can re-experience different parts of the lesson at a later place and time of their choosing, bringing benefit to teachers, those who support them, and researchers. Kosko et al. (2020) found that pre-service teachers observed all segments of the classroom whilst watching 360-degree video (recorded from a central point in the room) and made more observations of student actions in their written noticing. This represented an improvement on the use of conventional video. The ability to change position as a viewer could make it easier to engage directly with complex teaching situations. Teachers benefit from revisiting such complex activities from different perspectives (Brophy, 2004), moving beyond observational reflection to more critical productive engagement (Davis, 2006).

Furthermore, if 360-video can retain the sensation of being spatially present for the viewer, then teachers will have the opportunity to access richer, more productive experiences of teaching and learning from contexts both very different from and very similar to their own (Wang & Wiesemes, 2012, Borer et al., 2014). This could benefit those in geographically remote, displaced, or poorly resourced areas – or those

restricted due to disability – while addressing the complaint of many trainee teachers that they fail to spend sufficient time observing their own and others' classroom practice (Yadav, 2011).

The situated learning experiences of viewing 360-degree video with VR could therefore be shared not only locally, regionally or nationally but be also disseminated further afield as sharable Open Educational Resources (OER) (while paying attention to issues of child and adult safeguarding). They can thus serve to enhance the ways in which the familiar and the unfamiliar can be bridged. For example, research has shown that intercultural sharing of teaching practice through visits by teachers from one country to another, such as UK teachers visiting India, can create a cognitive, emotional and existential dissonance that challenges conceptions of teaching and supports personal development (Scoffham & Barnes, 2009).

Critical distance

Viewing any form of video affords the viewer a degree of critical distance from the subject. Conventional video has been found to make practice visible, such that the teacher can (re)view their lesson from the perspective of teacher or learner (Snoeyink, 2010) and develop perceptual skills, such as noticing and interpretation of classroom events (van Es & Sherin, 2008; Baker & Lee, 2011; Seidel et al., 2011). As their noticing skills develop, there appears to be a shift in a teacher's focus from descriptive observation towards greater interpretation and critical reflection, while at the same time challenging their existing assumptions (Sherin, 2007; Blomberg et al., 2014; Tripp & Rich, 2012). The quality and impact of video on the development of this professional vision has been found to be dependent on factors such as the relationship between the teacher and the teacher protagonist in the video, the nature of the prompts provided, the familiarity of the classroom setting, prior conceptions of teaching, and the teaching strategies used (van Es & Sherin, 2008; Seidel et al., 2005; Brophy, 2004; Beilstein, Perry & Bates, 2017).

360-degree video has been found to successfully enhance critical distance in several recent studies. Theelen et al. (2019) investigated whether a selection of 360-degree video clips of teaching practice could, when integrated into a series of three sessions taught by the researcher, improve pre-service teachers' level of interpretation of noticed classroom events as part of the development of their professional vision. The majority of participants were positive about the critical distances the application offered, reporting benefits such as exposure to different teaching styles and gaining greater insight into pupils' non-verbal cues.

Findings suggested that 360-degree video, when added to theoretical knowledge, increased pre-service teachers' professional vision and could potentially increase or accelerate their capacity to notice (Theelen et al., 2019). Meanwhile, in a study by Kosko et al. (2020), pre-service teachers were asked to view a seven-minute clip in one of three formats (conventional video, 360-degree video via a VR headset, and 360-degree video on a laptop), after having reviewed the teaching tasks to be shown in the video and predicted what they might notice. The video was viewed twice, with the student teachers writing down what they noticed after each viewing. Their findings indicate that pre-service teachers viewing 360-degree video attended to more pupil actions and gave richer descriptive references that demonstrated greater capacity to notice than those using standard video.

It is commonly argued that the consumption of video by teachers to support noticing skills and so on requires the viewing to be positioned within a carefully designed scaffolded activity (Brouwer, Besselink & Oosterheert, 2017; Beilstein, Perry & Bates, 2017). This helps to provide a 'focus' while contextually situating the viewing both socially and historically. A component of this support is the appropriate selection of video content, the length of the clip(s) and the number of times they are viewed. Yet the very roles of those who record, curate and scaffold can also be problematic and work to restrict the conceptual, as well as visual, frame of the viewer. Particularly when viewed on a VR headset, 360-degree video has the capability of rendering the viewer's body as a 'differential field' that can break out of, and stand beyond, its temporal and spatial shell (Lefebvre, 1991), thereby lessening the level of control exerted by others over the teacher's view of the classroom space. This gives the viewer greater agency to decide what is important and when. While Walshe & Driver (2019) allude to this potential for increased agency, they do not articulate further its potential for subverting established narratives by making space for new interpretations. Such potential could be particularly useful when educators are seeking to transform teaching practices and where a new 'pedagogy of space and time' (Lefebvre, 1991) needs to be established.

Where 360 videos are used to facilitate dialogue between teachers and teacher educators, the latter will be less certain about 'what' the teacher notices and will therefore need to make additional efforts to elicit and understand the teacher's experience, thereby potentially strengthening and deepening shared understanding and movement in the joint enterprise (Vygotsky, 1987).

Spatial presence

When using a VR headset, there will be an impact on the user's sense of presence, and theories of presence provide a useful frame by which to understand the experience of immersion in technologically-mediated environments. Spatial presence refers to the illusion of being in another location (Lombard & Ditton, 1997) and requires users to undertake a process of relocation of self from the real to the virtual as primary frame of sensory reference (Wirth et al., 2007), shutting out other physical realities present in the environment. While commonly associated with use of VR, it can also occur in less mediated contexts, such as watching conventional video (Wirth et al., 2007; Wissmath et al., 2009).

Kosko et al. (2019) have demonstrated that teacher professional noticing and situational awareness can be improved by the embodied interaction afforded by the perceptual capacity of 360-degree video and that viewing on VR headset will impact what in the 360-dgree space teachers attend to. Such studies indicate a potential link between the perception of experienced presence and teachers' self-efficacy and increased perceptual skills.

Watching 360-degree video with VR can deliver a rich, vivid immersive experience that heightens the viewer's sense of spatial presence (Banos et al, 2004; Wirth, 2007, Theelen et al, 2020) and of being 'at' the location where the video was recorded, even when viewed on a computer screen (Gold & Windscheid, 2020). There is a greater sense of immersion and disconnect (Olmos et al. 2018) from the 'actual' space and a sense of embodiment as the viewer relocates. This lends itself well to situated learning applications that involve authentic, complex situations, such as teaching and teacher education (Blomberg et al., 2014; Oonk et al., 2004; Saigal, 2012) and there are early indications that teachers can find using a headset a positive, fun, safe, and instructive experience, despite possible interface and physical issues (Theelen et al., 2019). Furthermore, functionality, such as multiple cameras that allow the viewer to move around a room, may also increase perceived immersion (Kosko et al., 2020).

Yet, while 360-degree video may create a sensory relocation and sense of embodiment (Ibrahim-Didi, 2015), the viewer does not step out of themself. In Bourdieu's terms, this means that, while the field changes, an individual initially retains the habitus with which they constitute the field as a meaningful world (Bourdieu, 1990). When habitus encounters an unfamiliar field, the consequent disjunctures can be

destabilising and transformative for the practitioner and their practice (Reay, 2010). Whether or not this is consciously experienced and reflected on by the viewer, the rapid spatial switching between actual and recorded spaces when using 360-degree video, and the refreshed layers of meaning overlaid when re-watching the same video artefact, complicate the sensation of spatial presence.

In addition, although using a VR headset is usually a singular experience, it can also be used effectively in peer or group social learning contexts (Borer et al., 2014), by combining individual viewings with a group review on a conventional flat screen. Indeed, one recommendation would be for better integration of software that mirrors what the VR headset is displaying. Instructors would find this functionality invaluable when training users in VR because at present they cannot see what images or menus the wearer of the headset is viewing.

Investigative space

The final theme proposed is the potential that 360-degree video offers observational and action researchers. Capturing the entire 360-degree space allows researchers to make a full record of any event, classroom-based or not, and re-watch, re-view and analyse it at a later date. The methodological potential of the technology is significant and would certainly negate many of the problems associated with making choices about what to film or frame when recording conventional video (Health et al., 2010). Gomez Cruz (2017) describes three potential uses for the technology in ethnographic research which could be relevant to teacher education research: placing the researcher in the field, sharing fieldwork experiences, taking visual fieldnotes. However, 360-degree video could potentially have a greater range of applications for the research process, such as enabling elicitation and stimulated recall, and for post-hoc analysis, such as improving data validation and reliability, thereby enhancing emerging fields of study. Classroom observers need robust pre-event training in order to minimise viewer disagreement (Muijs, 2006). 360-degree video could potentially shift this activity to post-event and even support a distributed method of checking validity and reliability. It is uniquely placed to support researchers checking inter-observer reliability (van der Lans, 2018) by allowing multiple virtual ‘visits’ rather than being limited to a single one conducted in person. 360-degree video may also be useful in mitigating for observer fatigue, cognitive load, and reactive effects, while

assisting with scholarship undertaken by teacher educators engaging in practice-based research (Srinivasan, 2016).

Moreover, 360-degree video and SVVR present new research opportunities, be these asking new research questions or probing existing ones further – e.g. could headset-mounted eye-tracking (Greenwald et al., 2016) help researchers understand more about the process of noticing classroom teaching, reveal differences in how in-service and pre-service teachers process visual information or help observe subtle changes to teaching perceptions and practice before and after an intervention? They also offer the possibility to add to researchers' ability to explore the social and temporal dimensions of pedagogical spaces (Nind, Curtin & Hall, 2016), enhancing our understanding of interactions between the physical and the social and distributions and reproduction of power within these spaces.

The choice of where and when to record and view 360-degree video can be assisted by a harnessing of teacher-owned technologies. In the pilot approach described in this paper, the central device used for processing, storing and viewing video is the smartphone – a commonly-owned technology even in low-income countries. Owning the means for production and consumption can matter and may be instrumental in engaging teachers and, by enabling them to view anytime-anywhere, achieve a more seamless (Wu et al., 2012) learning experience. VR headsets can work with many recent android phones, although there remain constraints such as the relatively low pixel densities and processor power of budget smartphones. While the technology has its limitations (Theelen et al., 2019), it is unclear whether this also applies to those in low- or medium-income contexts who have different expectations of and relationships with mobile devices.

This section has set out a four-part framework for the affordances and emerging opportunities of 360-degree video. The next section reports on a small-scale pilot that assessed the practicalities of using 360-degree video and the framework in a hitherto unstudied low-resource context.

Small-scale piloting of 360-degree video in a low resource context

In India, the publication of the 2009 National Curriculum Framework for Teacher Education marked a major policy shift and foregrounded the need to see teachers as 'crucial mediating agents through whom the

curriculum is transacted and knowledge co-constructed along with learners' (NCFTE, 2009, p.4). Of particular relevance was the clear focus of the framework on reflective practice, a capacity for self-directed learning, critical thinking and working in groups, and the ambition that all teachers should be provided with opportunities to observe learners, engage in self-learning and critical reflection, and become confident in the articulation of new ideas (MHRD, 2018). Historically there has been little developmental classroom observation in Indian schools (MHRD, 2012) and few examples of utilising video in teacher education. In part this absence of historic analysis of practice through video may be due to lack of equipment; 81% of government schools in Madhya Pradesh (location of the schools for this pilot) and 44% in India overall are without access to electricity (Government of India, 2020a, p.14-15). However, interest in the use of video to support teachers' professional learning is rapidly increasing. A recent programme, TESS-India (www.tessindia.edu.in), produced and shared 56 short video clips of teachers trying out new ideas in state school classrooms. This has generated considerable interest, with an average of 10 000 downloads per week from YouTube over the last 6 years. More informally, teachers are increasingly using their own smartphones to access materials and share video of their own classrooms with peers using applications such as WhatsApp (Adinolfi, 2016; Wolfenden et al., 2017; Wolfenden, 2015).

Methodology

The exploratory pilot was conducted in Madhya Pradesh, India, in December 2017 and involved two rural primary schools and the local primary teacher education centre, known as a District Institute for Education and Training (DIET). Over the previous three years the researchers had been involved in a large-scale teacher education partnership with the Madhya Pradesh State government. The strong professional relationships with key stakeholders and contextual knowledge developed through this programme facilitated access to the pilot sites.

Prior to the field activity, permissions were secured from state authorities, the principals of each school, the DIET, and the parents or guardians of children in the pilot schools. Purposeful sampling, with a preference for rural schools representing both lower and upper primary age groups, was used to identify the schools (Table 1). The parents or guardians of the pupils received and returned a copy of a consent form in Hindi – the language of instruction. Ongoing consent was sought from the teachers and children throughout the field

work. British Educational Research Association guidelines were followed with full approval from the researchers' own university ethics committee.

Table 1. Participating schools and DIET

	School 1	**School 2**	**DIET**
Number of pupils	66 pupils aged 5-9 years (lower primary)	83 pupils aged 9-12 years (upper primary)	Approx. 100 first year pre-service Approx. 100 second year pre-service teachers
Number of staff	3	3	12
Mains electricity	No	No	Yes
Wired / Mobile internet	No / Very poor	No / Intermittent	Yes
Location	Rural	Rural	Urban
Distance	23km from DIET	15km from DIET	72 km from state capital

The pilot fieldwork consisted of two stages: first, recording of 360-degree video in classrooms at two rural primary schools, and second, viewing of the video clip within semi-structured interviews with representatives from three key stakeholder groups: the primary teachers who had been filmed, teacher educators, and trainee teachers from the DIET. Interviews were conducted in a combination of English and Hindi, audio recorded and subsequently transcribed and translated into English. These interviews were first open coded against the four dimensions outlined above as *a priori* themes. Then initial and focused coding were used to identify and, where necessary, group emergent sub-themes (Charmaz, 2014). To these additional codes we added information about whether the comment related to the participants' first or second viewing. The following coding structure was determined: Opening observation (7 sub-themes), Critical distance (8), Spatial presence (5) and Investigative space (6).

In the first stage, multiple clips from two lessons at each participating school were recorded by one 360-degree camera located in the centre of the classroom and one at the rear. The teachers were given no

direction about what to teach so what was recorded was whatever they had planned to teach that day. The cameras were set up before the class began and mounted on a monopod with small tripod at base for stability. Camera height was at, or just above, the eye-level of the pupils. Located in a separate room for the duration of the lesson, researchers controlled the recording using Samsung's mobile app and Bluetooth connection to the cameras. This approach was chosen to avoid any disruption caused by the researchers being present in, entering or leaving the classroom. Clips of between three and five minutes in length were recorded throughout the lesson. This is consistent with clip lengths recommended by Tripp & Rich (2012) and used by Theelen et al. (2019), Geng (2019) and Kosko et al. (2020). After each lesson, video was transferred directly from each camera via Bluetooth to a smartphone. It took around ten minutes for a three-minute clip to be processed into the 360-degree rectilinear video, meaning teachers could view a recording of an excerpt of their lesson less than an hour after teaching it.

The second stage consisted of semi-structured interviews (n=7) (Table 2) with our three key stakeholder groups. Teachers (3) viewed clips of their own lesson and teacher educators (2) and trainee teachers (2) were shown the same clips. This approach gave us different perspectives on the same examples of practice. For each lesson, the clip recorded closest to the mid-point of each lesson was used. By this point we considered that the pupils and teacher would be accustomed to the camera and there was more likelihood of some pupil activity rather than merely teacher talk from the front. This consistency in the selection criteria also aimed to avoid any potential bias and purposive selection of clips by the researchers. All participants were volunteers and were selected on a first-come basis in response to an invitation relayed ahead of the visit. There were four male and three female interviewees.

Table 2: Interview details

Interviewee	Gender	Location
(In-service) Teacher 1	Male	School 1
(In-service) Teacher 2	Female	School 1
(In-service) Teacher 3	Female	School 2
Teacher Educator 1	Male	DIET

Teacher Educator 2	Male	DIET
Trainee Teacher 1	Male	DIET
Trainee Teacher 2	Female	DIET

The interviews were led by the UK researchers, with the assistance of two locally-based bilingual team members who acted as interpreters. The interviews were preceded by a short demonstration of VR headsets using a static 360-degree image of the interior of a large, architecturally striking building. This was intended to give participants confidence in handling and viewing images. A static image was chosen to minimise any initial disorientation and impact on the main study (which involved viewing moving images).

Participants were first asked about their prior experience of being filmed and of using video in their teaching and professional development. Next, the participants viewed a 360-degree video clip using a mobile VR headset and were then asked three questions about their experience: what did you watch in the clip? What interesting things did you notice when watching the clip? And why do you think these were interesting? This process was repeated a second time using the same clip. The interview concluded with four final questions: was it helpful to watch the lesson from a different perspective? As a result of watching the video, is there anything you would change about your practice or do differently next time? Would you be interested in using 360 video again? What issues or difficulties could arise in rolling out this technology so that many schools have access to it? The interviews lasted between 20–40 minutes. Detailed fieldnotes were taken throughout and cross-referenced during later analysis.

Technical planning

Our intended approach presented a range of technical, methodological and logistical challenges. Our choice of pilot location meant that all technology had to be portable, capable of being charged without mains power, and used without access to the internet. In this context, the recording, editing, transferring and viewing 360-degree video on the same day required the careful selection and testing of the intended combination of recording and viewing technologies. Figure 2 presents an illustration of the technology chosen and the process of recording and viewing the 360-degree video.

[FIG_2.JPG]

Figure 2. (a) Samsung 360-degree camera and Samsung smartphone in process of being set in place (clicked in to clips on each side) to a Samsung Gear headset. (b) Screenshot of 360-degree video recording before processing.

We were aware that cost, size and weight could all be important factors for future potential uptake in low- and medium-resource countries so we chose two of the cheapest 4k cameras available at the time. For the interviews, we used a Samsung 360-degree omnidirectional camera ($100) and Samsung VR headset ($50) fitted with a Samsung S6 smartphone ($300) (Figure 2). At the time we had found no precedent for such an application so we adopted contingency planning for each stage. In practice, the combination of technologies performed well and our contingencies were not required.

Pilot study findings

Analysis of the interview data, following the process described earlier, indicated some endorsement of the four narrative themes and provided insights into the particular ways that teachers, trainee teachers and teacher educators may interpret, frame and talk about these. This section highlights aspects of the sub-themes identified and is followed by a discussion of the feasibility of the use of the technology in low-resource contexts.

The initial questions revealed that the teacher educators and trainee teachers had used conventional videos of teaching practice in their training but had no prior knowledge of 360-degree video. The three teachers had not had their practice video-recorded before. All participants owned a smartphone and this was a common method of accessing the internet. In all the video clips used, teaching was predominantly conducted from the front of the classroom using a blackboard and with reference to a textbook. The subjects taught were mathematics, Indian currency and the human body. Most comments were made in relation to the first three narrative themes.

Opening observation

Both teacher educators responded enthusiastically to the experience and potential of observing practice using the VR headsets. Teacher Educator 1 explained how a view of the entire classroom helped him take a holistic view of lesson and detail his observations – for example, that some children have opened their books, some have not. Teacher Educator 1 echoed this view commenting 'this is definitely effective; we are able to monitor through the video to the teacher and his teaching skills, as well as minutely look at the activity level of all the children in the class. You can see the whole classroom situation very closely, to see what the kids are doing at that time'. When asked if the 360-degree video represented an improvement on the usual approach to observing classroom practice, Teacher Educator 1 explained that 'regular monitoring that we do as a DIET faculty is usually from the back door of the classroom. We cannot see the activities of all children. But from this video, this technology we can observe each and every student's activity as well as teachers.'

The teacher educators gave a number of possible uses for 360-degree video in their work with trainees. Conventional video was already used in the DIET for teaching. However, Teacher Educator 2 and Trainee Teacher 1 both suggested that reviews of 360-degree video could add value to conversations between the teacher educator and pre-service trainee about improvements to practice. One example given of this potential use as a mediating artefact was to have pre-service teachers review 360-degree video clips of one another's lessons or to engage in learning activities utilising pre-recorded 360-degree sample lessons facilitated or delivered by the teacher educators themselves. The teacher educators and trainee teachers were also supportive of using 360-degree video to augment theoretical discussion of practice in lectures by immersing trainee teachers in classroom practice. These could be explored in subsequent scholarships to establish their value.

The in-service teachers also expressed an interest in watching videos of their peers. Teacher 3, for example, noted how 'every teacher has different [approaches] … [so] it would be very good for me if I could see what kind of techniques [my colleagues] are applying during teaching sessions.' In itself, such an interest in sharing and disseminating practice could also apply to conventional video. However, these comments were made in the context of the teacher having experienced the lesson as a virtual observer immersed in the centre

of the classroom with a 360-degree field of view. Further study would provide further insight into how such a process of 'deferred' peer observation could support professional development and the sharing of practice within schools.

Critical distance

In the context of national teaching policy, the value of 360-degree video in literally placing children's learning at the centre and in focusing on the relationship between teacher and pupils is important. One sub-theme to emerge was that viewing 360-degree video appeared to help participants achieve a degree of critical distance while feeling more connected and attentive. Teacher 1 noted that 'it makes me more attentive to what is happening. I see things I hadn't noticed', elaborating that, after his first viewing, he noticed that he had forgotten to include a topic related to the subject being taught and that those sitting in the last row were paying less attention. Here the teacher is making a connection between his actions and the pupils' responses. When asked how the latter issue could be addressed, he proposed that he move around the classroom more. On second viewing, he made more detailed observations of individual pupils and reflected on how they were responding to him, noting that most were 'listening attentively and were very absorbed in the lesson. Some of them were making notes.' The identification of future changes to practice was also evident in the interview with Teacher 2. She identified opportunities for improvement in her practice after noticing that that some pupils were not concentrating and that there had been periods when she had her back to the class which also obscured the blackboard. She became more self-aware of her positioning relative to different sightlines that students had, remarking 'I need to move to [the other] side after I have written on the board so that the kids do not have to see from the side.' Her assessment was corroborated by Teacher Educator 2 and Trainee Teacher 2 who both viewed a clip of Teacher 2 and noticed the same issue.

Our interviews therefore showed that, even with as few as two viewings, it was possible to discern signs of a perceptual shift from teacher-centric to pupil-centric perspectives. On first viewing, the gaze of the teachers, trainee teachers and teacher educators tended to fall on the teacher protagonist, and was therefore orientated towards the front of the classroom. This changed for the second viewing. As outlined above, Teacher 1 was conscious of this shift, explaining 'the first time I viewed the clip, I focused on myself, but this [second] time I noticed what my pupils were doing' and Teacher 3 remarked '[in the first viewing] I watched the

children but not properly, but this [second] time I watched each and every child with more attention, what they were doing.

As expected and consistent with other studies, all those interviewed found that viewing 360-degree video helped them to notice aspects of the teaching (either their own or that of another practitioner) and identify steps for practice improvement. There was also recognition of the value of being able to re-watch a lesson within hours, with Teacher 1 noting ‘it’s very helpful to see oneself from another perspective, [for] if you have the opportunity to analyse a lesson in this way, you can then amend and supplement your practice the following day.’ While near instant review is commonly possible for conventional video, one original component of our study was to trial the more complex process of recording and playback of 360-degree video to teachers on the same day as the lesson was delivered.

Spatial presence

It was with respect to the deeply immersive experience and sense of spatial presence that participants often made their most substantial remarks. It is clear that watching 360-degree video in VR was considered a distinct experience from that of watching conventional video, with Teacher 2 explaining that viewing on a ‘mobile looks like we are just looking at pictures and in [the VR] we were able to experience what we could see ourselves’ later, noting that ‘more and more senses are activated: looking eyes, listening, watching, speaking.’ Teacher Educator 2 described the feeling of being ‘live’ in the classroom and explained that, unlike being at the back of the room, as when doing conventional classroom observation, they felt this experience had helped them gain a virtual presence in the classroom and feel connected. Other interviewees reported similar experiences. Teacher 1 observed ‘it’s interesting to see myself in this way. It feels like I am in the classroom,’ while Teacher 3 evoked a similar idea of intimacy, recollecting how ‘I feel that I can reach each and every child just watching this video.’ Teacher Educator 1 talked of the value in being able to ‘see teacher and children, the entire class’, after a viewing of the video where they turned to observe and monitor interactivity in different sections of the classroom.

Not only was the experience considered engaging, but it was also captivating. Emotional response emerged as a distinct sub-theme, with spatial presence appearing to help engage the teacher and heighten their engagement with pupils. For Teacher 3, the experience created a positive emotional response and, after her

first viewing of the video, she remarked that ‘when we watch ourselves with the children, we understand how much the children are enjoying, which feels like a good experience.’ It is uncertain whether a similar response would have been experienced if watching this as conventional video on a flat screen.

We had anticipated that some participants would experience disorientation when first viewing 360-degree video. However, all quickly became accustomed to the standing and greater physical movement required to turn head and body when ‘looking’ around the classroom. This may have been helped by the introductory activity which used a static 360-degree photograph to familiarise and orientate the viewer.

Investigative space

From the perspective of a researcher, we consider that the recording and viewing of 360-degree video provides a rich documentation of the teaching and learning taking place in the classroom. We have watched the video clips many times since and found them to be a valuable means of sharing the experience with a research colleague who was unable to travel to the field sites. Teachers did not feel the presence of the camera in the classroom caused undue disruption and the pupils did not appear to be staring at or avoiding the camera. However, as we have no prior observations of these teachers, we are unable to substantiate such views. It is likely that our presence in the school was a much greater disruptor than the equipment, hence these impressions would need investigating further.

Discussion

An essential step in delivery of SDG 4 will be the disruption of the classroom discourse, regimes and routines that support and reproduce didactic teaching approaches and assumptions. This will make space for pedagogic change which is more participatory and inclusive for all learners. It is against this backdrop that the new technologies of 360-degree video and SVVR could possibly contribute. In terms of the conceptual framing we outline (Figure 1), the interplay between spatial presence and critical distance could offer tools to nurture the situated critical reflexivity needed to deliver change in teachers’ habitus (Bourdieu, 1990) and challenge deeply embedded relationships that appear resistant to change (Poonam, 2014; Azam & Kingdon, 2015). At the same time, a combination of opening observation and creating an investigative space could

raise visibility and awareness of practice (Zhang et al., 2011), while supporting more effective means to observe, review, monitor, and research the nature of practice change.

However, we also observed a tension between our themes of critical distance and spatial immersion as a consequence of opening observation using 360-degree video. On the one hand SVVR enables a stepping back from classroom interactions to establish critical distance for meaningful enquiry into practice, on the other hand the hugely immersive experience draws in the observer and places them once again at the centre of the interactions. How might these be reconciled? Appropriate, well designed and articulated mediation and guidance may help users to navigate these two potentially conflicting issues associated with self and location. This example illustrates the importance of further investigation into the relationships between the constituent elements on which narrative for 360-degree video for teacher education is being built.

Our exploratory pilot was designed to explore whether the emerging narrative around 360-degree video, as represented in the four elements of our conceptual framing, might be useful in making sense of how 360-degree video can operate in challenging, low-income contexts. There were some commonalities across the themes. In-depth analysis of the interviews reveals glimmers of how the technology might help teachers feel spatially present and act as a mediating artefact (Kosko et al, 2020; Theelen et al, 2020) to support teachers in focusing more on how their pupils are interacting – with each other, with their teacher – and to become more familiar with their pupils, their prior knowledge, experiences and their learning needs. Because 360-degree video lacks a predetermined focus on teacher or pupil, we believe the technology may work to place greater emphasis on the classroom as a holistic space of interaction.

The pilot also demonstrated the feasibility of using such technologies in low resource schools. As discussed above, it may also offer a more comprehensive tool than conventional video, albeit recognising that, as noted by participants, extensive resource and support will be required to both deploy the technology at scale and open up possibilities for the 360-degree video clips to mediate reflective discourse.

A critical challenge to utilising 360-degree video and SVVR in low- and medium- income contexts, also mentioned by participants, is access to these technologies. This could be facilitated by finding ways to pair teacher-owned smartphones with VR viewers costing less than $10. For teachers engaged in school-based professional development, owning the main means for production and consumption can matter and may be

instrumental in helping to engage them. By enabling teachers to view video anytime, anywhere, it may achieve a more seamless learning experience. This being said, although budget smartphones are improving, many still lack the high pixel densities, screen sizes, sensors and processor power required to deliver an adequate VR experience. Our pilot benefited from a relatively seamless integration of the hardware used for recording, image processing and viewing (all manufactured by Samsung). However, since undertaking the field research, hardware and software technologies have continued to evolve.

The potential use of 360-degree video in SVVR applications for teaching pupils in classrooms has been investigated for a range of subject areas from natural science and geography to art history and languages. Example applications such as inquiry learning through virtual fieldtrips (Minocha et al., 2017; Jong et al., 2020), peer assessment (Chien et al., 2020) and self-regulated learning (Wu et al., 2021) all demonstrate how researchers combined the key affordance we have identified of opened observation (i.e. opening spaces to pupil observation) critical distance and spatial presence to achieve improved learning, greater motivation and realism and to build learners' self-efficacy and confidence. Less attention has been paid to how pupils can record their own 360-degree video for use in research and analysis (Conchrane, 2016) as part of their investigative space, although some studies are moving in this direction (Chien et al., 2020, S.-C. Chang et al., 2018). Our research highlights the value in providing authentic recordings of practice and, like Geng et al. (2021), identifies the challenge of building acceptance. It is possible that greater use of 360-degree video for professional development could translate into greater use in teaching practice however this, and relevance to other professional training contexts, would need further exploration. For example, in the training of nurses in issues relating to childbirth, C.-Y. Chang et al. (2019) report an increase in achievement, motivation and satisfaction, with trainee nurses reporting benefits relating to opened observation (feeling able to 'observe in depth') and critical distance ('ask more questions') and whilst Bhowmick et al.'s (2018) study of nurses in India did not specifically test viewing 360-degree content on a headset, it does highlight how spatial presence and the sense of 'being there' improved significantly when viewing interactive VR content on a headset when compared to watching videos on a smartphone.

While they manifest in different ways, we also note that all four of our dimensions comprise, and will in turn be influenced by, an affective component associated with emotional responses to 360-degree video.

Affective state can be a critical mediator of teachers' attention, motivation and cognitive participation influencing how they engage in TPD type activities, including those which involve viewing of video from their own classrooms (Pekrun, 2006; C.-F. Chang et al., 2018). We have not been able to locate any studies on teachers' emotional responses to 360-degree video of their own classrooms. However, studies have found that greater immersion and use of 360-degree video compared to conventional video can give greater positive affect and higher levels of emotional response (Rupp et al., 2019; Voigt-Antons et al., 2020; Ulrich et al.,2019). Our observations of participants and their self-reports indicate that affect or emotional responses are threaded through and influence how 360-degree is accepted and used. More work may be required to understand how the framework should recognise this.

We found that the quality of video was not sufficient to show fine detail (such as writing on blackboards) although it did provide sufficient detail of facial expressions. The issue of fine detail is improving as the technology develops. However, greater image size and bitrates may present new implementation challenges. Audio was considered satisfactory, although the lessons recorded did not involve activities such as group work, which may have been harder to capture. Those interviewed generally seemed satisfied with the quality of video and sound, but this might have been due to the novelty of the experience and a reluctance to engage explicitly in critiquing the technology with the researchers present.

Analysis of the interviews highlighted further challenges: the need for local training, guidance and technical support in operating the equipment; barriers to sharing 360-video and images where internet connectivity is poor; and the establishment of effective ways of loaning and sharing equipment across a district. Not unexpectedly, we too recognised the need for support and scaffolding around the video viewing (Brouwer, Besselink & Oosterheert, 2017) if to be used as a prompt for reflective practice. Despite the ambitions of the NCFTE (2009), progress in implementing more participatory pedagogies has been slow and many teachers in India have little experience of structured classroom observation and few opportunities to develop skills in reflecting practice. Where it exists, classroom observation is still widely associated with monitoring teacher practice to ensure that they conform to long-held ideals of behaviour, rather than focusing on how pupils are developing their knowledge and understanding through the activities of the lesson (Wolfenden & Adinolfi, 2019).

Our study is unique in capturing perspectives from a difficult-to-reach group of practitioners in the Global South and in demonstrating that 360-degree video recording and viewing can be done in the field. These alone represent significant accomplishments, even though our study was limited by the practical, cultural and resource constraints that we faced in conducting field research in this context. While efforts were made to involve teachers, teacher educators and trainee teachers, we did not have the luxury of being able to select which lessons we observed or gain insights from those less willing to volunteer to participate.

Conclusion

This paper makes two significant contributions to the area of enquiry associated with the use of 360-degree video and SVVR in teacher education and professional development. Firstly, it describes and develops four key dimensions of the emerging narrative associated with 360-degree video and brings these together into a conceptual framing. Future work could seek to understand how these operate together at a practical and theoretical level with respect to teacher learning, as well as a broader range of contexts. Secondly, this paper reports a small-scale pilot that explores the practical possibilities of using the technology and the framework in the context of teacher professional development in India, a context not hitherto represented in the literature. Together, these contributions take the debate beyond the use and evaluation of 360-dgree video in well-resourced high-income contexts (Major & Watson, 2018; Gaudin & Chaliès, 2015; Kosko et al., 2020).

Overall, we find that 360-degree video overcomes some of the key limitations associated with conventional video and could potentially help make classroom practice more visible not only to teachers and their peers - whether local or further afield - and teacher educators, but also to educational researchers. By delivering a more complete ‘window into practice’ (Zhang et al., 2011, p.459) a range of professional learning activities can be better supported, ranging from personal reflection (e.g. Tripp & Rich, 2012) to social peer learning (e.g. Borko et al., 2008). Access to a library of pre-recorded 360-degree taught lessons may also help trainee teachers gain valuable classroom observational experience and accelerate the rate they develop key skills such as noticing.

Our initial findings also that hint at how 360-degree video and VR technology can provide an ‘investigative space’ to researchers working in contexts that are costly to travel to in person, remote, or resource-poor; to those requiring greater methodological rigour in their analysis of practice; or to contexts where the presence

of the researcher has the potential to be highly disruptive to the activity being observed. This study supports the need to recognise 360-degree video as a distinct area of academic interest with practical and methodological benefits. Furthermore, it demonstrates that 360-degree video has the potential, if implemented effectively, to support teachers and teacher educators in delivering the transformation of classroom practice required for the attainment of SDG 4 in low- to medium-income countries.

References

Adinolfi, L. (2016). Utilising tablets and one-to-one coaching to create classroom videos for teacher development in India. In G. Pickering & P. Gunashekar (Eds.) *Ensuring quality in English language teacher education.* New Delhi: British Council.

Akyeampong, K. (2017). Teacher educators' practice and vision of good teaching in teacher education reform context in Ghana. *Educational Researcher*, 46(4), 194-203.

Azam, M. & Kingdon, G.G. (2015). Assessing teacher quality in India. *Journal of Development Economics*, 117(C), 74-83.

Baker, A. A. & Lee, J. (2011). Mind the gap: unexpected pitfalls in doing classroom research. *The Qualitative Report*, 16(5), 1435–1447.

Beilstein, S. O., Perry, M. & Bates, M.S. (2017). Prompting meaningful analysis from pre-service teachers using elementary mathematics video vignettes. *Teaching and Teacher Education*, 63, 285-295.

Blomberg, G., Sherin, M. G., Renkl, A., Glogger, I. & Seidel, T. (2014). Understanding video as a tool for teacher education: investigating instructional strategies integrating video to promote reflection. *Instructional Science,* 42(3), 443–463.

Banos, R.M., Botella, C., Alcaniz, M., Liano, V., Guerrero, B. & Rey, B. (2004). Immersion and emotion: their impact on the sense of presence. *CyberPsychology and Behaviour, 7(6).*

Bhowmick, S., Darbar, R. & Sorathia, K. (2018). Pragati: design and evaluation of a mobile phone-based head mounted virtual reality interface to train community health workers in rural India. *NordiCHI '18: Proceedings of the 10th Nordic Conference on Human-Computer Interaction*, (pp. 299-310). ACM.

Borko, H., Jacobs, J., Eiteljorg, E. & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, 24(2), 417-436.

Borko, H., Koellner, K., Jacobs, J. & Seago, N. (2010). Using video representations of teaching in practice-based professional development programmes. *ZDM Mathematics Education*, 43, 175-187.

Borer, V. L., Ria, L., Durand, M. & Muller, A. (2014). How do teachers appropriate learning objects through critical experiences? A study of a pilot in-school collaborative video learning lab. *Form@re : Open Journal per la Formazione in Rete*, 14(2), 63-74.

Bourdieu, P. (1990). *In other words: essays towards a reflexive sociology*. Cambridge: Polity Press.

Brophy, J. (Ed) (2004). *Using video in teacher education*: *advances in research on teaching, Vol 10,* Oxford: Elsevier.

Brouwer, N., Besselink, E. & Oosterheert, I. (2017). The power of video feedback with structured viewing guides. *Teaching and Teacher Education*, 66, 60-73.

Chang C.-F., Gröschner, A., Hall, N.C., Alles, M., Seidel, T. (2018). Exploring Teachers' Emotions via Nonverbal Behavior During Video-Based Teacher Professional Development. *AERA Open*. October 2018.

Chang, C.-Y., Sung, H.-Y., Guo, J.-L., Chang, B.-Y. & Kuo, F.R. (2019). Effects of spherical video-based virtual reality on nursing students' learning performance in childbirth education training, *Interactive Learning Environments*. Published online DOI:10.1080/10494820.2019.166185

Chang, S.-C., Hsu, T.-C., Chen, Y.-N. & Jong, M.S.-Y. (2018). The effects of spherical video-based virtual reality implementation on students' natural science learning effectiveness. *Interactive Learning Environments*, 28(7), 915-929.

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 and Education*, 146, 103751.

Cochrane, T. (2016). Mobile VR in education: from the fringe to the mainstream. *International Journal of Mobile and Blended Learning*, 8(4), 44-60.

Cross, S., Wolfenden, F. & Adinolfi, L. (2018). Transforming classroom observation and professional development with 360-degree video and mobile VR. *8th Annual mEducation Alliance Symposium*, 6-8 November 2018, Washington DC, USA.

Davis, E.A. (2006). Characterizing productive reflection among preservice elementary teachers: seeing what matters. *Teaching and Teacher Education, 22*, 281–301.

Dyke, M., Harding, A. & Liddon, S. (2008). How can online observation support the assessment and feedback, on classroom performance, to trainee teachers at a distance and in real time? *Journal of Further and Higher Education,* 32(1), 37–46.

Estapa, A. & Amador, J. (2016). Wearable cameras as a tool to capture preservice teachers' marked and recorded noticing. *Journal of Technology and Teacher Education*, 24(3), 281-307.

Fernandez, M. (2017). Augmented virtual reality: How to improve education systems. *Higher Learning Research Communications,* 7(1), 1-15.

Gaudin, C. & Chaliès, S. (2015). Video viewing in teacher education and professional development: A literature review. *Education Research Review*, 16, 41-67.

Geng, J., Chai, C-S., Jong M.S.-Y. & Luk, E.T-H. (2019). Understanding the pedagogical potential of interactive spherical video-based virtual reality from the teachers' perspective through the ACE framework. *Interactive Learning Environment*, 1-16. Published online 18 March 2019.

Gold, B. & Windscheid, J. (2020). Observing 360-degree classroom videos - effects of video type on presence, emotions, workload, classroom observations, and rating of teaching quality. *Computers and Education*, 156, 103960.

Gomez Cruz, E. (2017). Immersive reflexivity: using 360-degree cameras in ethnographic fieldwork. In E. Gomez Cruz, S. Sumartojo & S. Pink (Eds.). *Refiguring techniques in digital visual research.* London: Palgrave Pilot.

Government of India (2012). *Vision of Teacher Education in India: Quality and Regulatory Perspective, Report of the High Powered Commission on Teacher Education Constituted by the Hon'ble Supreme Court of India, Vol. 1.* New Delhi: Ministry of Human Resource Development.

Government of India (2020a). *Demands of Grants 2020-21 (Demand No.58) of the Department of School Education and Literacy*. Report No. 312. Rajya Sabha Secretariat, Parliament of India: New Delhi. Available at: https://rajyasabha.nic.in/rsnew/Committee_site/Committee_File/ReportFile/16/123/312_2020_3_12.pdf

Government of India (2020b). *National Education Policy*. Ministry of Human Resource Development. Available at: https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf

Greenwald, S.W., Loreti, L., Funk, M., Zilberman, R. & Maes, P. (2016). Eye gaze tracking with Google Cardboard using Purkinje Images. *Proceeding of the 22nd ACM conference on virtual reality software and technology*, 2 November 2016, 19-22.

Grossman, P., Hammerness, K. & McDonald, M. (2009). Redefining teaching, re-imagining teacher education, *Teachers and Teaching: theory and practice*, *15*(2), 273-289.

Heath, C., Hindmarsh, J. & Luff, P. (2010). Video in qualitative research: analysing social interaction in everyday life. London: SAGE.

Ibrahim-Didi, K. (2015). Immersion within 360 video settings: capitalising on embodied perspectives to develop reflection-in-action within pre-service teacher education. In T. Thomas, E. Levin & P. Dawson (Eds), *Research and development in Higher Education: learning for life and work in a complex world,* (pp.235-245). Melbourne: HERDSA.

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.

Kavanagh, S., Luxton-Reilly, A., Wuensche, B. & Plimmer, B. (2016). Creating 360^0 educational video: a case study. *OzCHI '16 Proceedings of the 28th Australian Conference on Computer-Human Interaction*.

Kidwai, H., Burnette, D., Rao, S., Nath, S., Bajaj, M. & Bajpai, N. (2013). In-service teacher training for public primary schools in rural India: findings from District Morigaon (Assam) and District Medak (Andhra Pradesh). *Mumbai Working Paper Series, 12.* Columbia Global Centers. Available at: https://academiccommons.columbia.edu/doi/10.7916/D8HT2PRV

Kosko, K.W., Ferdig, R.E. & Zolfaghari, M. (2020). Preservice teachers' professional noticing when viewing standard and 360 video. *Journal of Teacher Education*, July 2020, 1-14.

Lee, F. & King, A. R. (1966). *The use of closed circuit television to improve teacher effectiveness: a research project using closed circuit television as a medium for classroom observation.* California, USA: University of Michigan.

Lee, S. H., Sergueeva, K., Catangui, M. & Kandaurova, M. (2017). Assessing Google Cardboard virtual reality as a content delivery system in business classrooms. *Journal of Education for Business*, 92(4), 1-8.

Lefebvre, H. (1991). *The production of space*. Oxford: Blackwell.

Liang, J. (2015). Live video classroom observation: an effective approach to reducing reactivity in collecting observational information for teacher professional development, *Journal of Education for Teaching*, 41(3), 235-253.

Lombard, M. & Ditton, T. (1997). At the heart of it all: the concept of presence. *Journal of Computer Mediated Communication*, 3(2).

Maheshwari, A. N. & Raina, V.K. (1998). In-service training of primary teachers through interactive video technology: an Indian experience. *International Review of Education*, 44(1), 87-101.

Major, L. & Watson, S. (2018). Using video to support in-service teacher professional development: the state of the field, limitations and possibilities. *Technology, Pedagogy and Education*, 27(1), 49-68.

Marsh, B., Mitchell, N, & Adamczyk, P. (2010). Interactive video technology: enhancing professional learning in initial teacher education. *Computers & Education*, 54(3), 742-748.

MHRD (2018). *School education*. Department of School Education and Literacy, Ministry of Human Resource Development: New Delhi, India. Webpage. Retrieved at: http://mhrd.gov.in/teacher-education-overview

Ministry of Human Resources and Development (MHRD). (2012). *Justice Verma Commission Volume 2, Vision of teacher education in India quality and regulatory perspective vision of teacher education in*

India quality and regulatory perspective (1). New Delhi: Ministry of Human Resources and Development, Government of India.

Minocha, S., Tudor, A.-D. & Tilling, S. (2017). Affordances of mobile virtual reality and their role in learning and teaching, In: *The 31st British Human Computer Interaction Conference*, 3rd - 6th July 2017, University of Sunderland, UK.

Muijs, D. (2006). Measuring teacher effectiveness: some methodological reflections. *Education Research and Evaluation*, 12(1), 53-74.

Murphy, P. & Wolfenden, F. (2013). Developing a pedagogy of mutuality in a capability approach - teachers' experiences of using the open educational resources (OER) of the teacher education in sub-Saharan Africa (TESSA) programme. *International Journal of Educational Development*, 33(3), 263–271.

National Curriculum Framework for Teacher Education (NCFTE) (2009). *Towards preparing professional and humane teacher*. New Delhi: National Council for Teacher Education.

Nind, M., Curtin, A. & Hall, K. (2016). *Research methods for pedagogy*. London: Bloomsbury.

Olmos, E. Cavalcanti, J.F., Soler, J.-L., Contero, M. & Alcañiz, M. (2018). Mobile virtual reality: a promising technology to change the way we learn and teach. In S. Yu, M. Ally, & A. Avgoustos (Eds), *Mobile and ubiquitous learning, perspectives on rethinking and reforming education*, (pp.95-105). Singapore: Springer Nature.

Oonk, W., Goffree, F. & Verloop, N. (2004). For the enrichment of practical knowledge: good practice and useful theory for future primary teachers. In: J. Brophy (ed) *Using video in teacher education*, (pp.131-167). Oxford: Elsevier.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, 18(4), 315–341.

Pew Research Centre (2019). Smartphone ownership is growing rapidly around the world, but not always equally. *Pew Research Centre*.

Poonam, B. (2014). Problematising teacher education practice in India: developing a research agenda. *Education as Change*, 18(1), 5-18.

Popova, A., Evans, D.K., Breeding, M.E. & Arancibia, V. (2018). *Teacher professional development around the world: the gap between evidence and practice.* World Bank Policy Research Working Paper 8572: World Bank. Available at: http://documents.worldbank.org/curated/en/349051535637296801/pdf/WPS8572.pdf

Putnam, R.T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29(1), 4-15.

Reay, D. (2010). 'It's all becoming a habitus': beyond the habitual use of habitus in educational research. *British Journal of Sociology of Education*, 25(4), 431-444.

Rupp, M. A., Odette, K. L., Kozachuk, J., Michaelis, J. R., Smither, J. A., & McConnell, D. S. (2019). Investigating learning outcomes and subjective experiences in 360-degree videos. *Computers and Education*, 128, 256–268.

Saigal, A. (2012). Demonstrating a situated learning approach for in-service teacher education in rural India: The Quality Education Programme in Rajasthan. *Teaching and Teacher Education*, 28(7), 1009-1017.

Schweisfurth, M. (2011). Learner-centred education in developing country context: from solution to problem? *International Journal of Educational Development*, 31(5), 425-432.

Scoffham, S. & Barnes, J. (2009). Transformational experiences and deep learning: the impact of an intercultural study visit to India on UK initial teacher education students. *Journal of Education for Teaching: International Research and Pedagogy*, 35(3), 257-270.

Seidel, T., Prenzel, M., Rimmele, R., Schwindt, K., Kobarg, M. & Meyer, L. (2005). Do videos really matter? The experimental study LUV on the use of videos in teachers' professional development. *Eleventh Conference of the European Association for Research on Learning and Instruction*, 23-27 August 2005, Nicosia, Cyprus.

Seidel, T., Strümer, K., Blomberg, G., Kobarg, M. & Schwindt, K. (2011). Teacher learning from analysis of videotaped classroom situations: does it make a difference whether teachers observe their own teaching or that of others? *Teaching and Teacher Education*, 27(2), 259-267.

Sherin, M.G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed) *Using video in teacher education, (pp.1-27).* Oxford: Elsevier.

Sherin, M.G. (2007). The development of teachers' professional vision in video clubs. In R. Goldman, R. Pea, B. Barron & S.J. Derry (Eds), *Video research in the learning sciences.* Mahwah, NJ: Lawrence Erlbaum.

Snoeyink. R. (2010). Using video self-analysis to improve the 'withitness' of student teachers. *Journal of Computing in Teacher Education*, 26(3), 101-110.

Srinivasan, R. (2016) Teaching about teaching: Examining the pedagogy of teacher education in India. *Higher Education for the Future*, 3(2), 197-21.

Theelen, H., van den Beemt, A. & den Brok, P. (2019). Using 360-degee videos in teacher education to improve preservice teachers' professional interpersonal vision. *Journal of Computer Assisted Learning*, 35(5), 582-594.

Tripp, T. & Rich, P. (2012). Using video to analyse one's own teaching. *British Journal of Educational Technology*, 43(4), 678-704.

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

UNESCO (2013). *Teaching and learning: achieving quality for all 2013-14*. Education for All Global Monitoring Report, Paris: UNESCO.

UNESCO (2015). *Education for all 2000-2015: achievements and challenges.* Education for All Global Monitoring Report, Paris: UNESCO.

UNESCO (2017). *Accountability in education: meeting our commitments*. Global Education Monitoring Report, Paris: UNESCO.

van der Lans, R.M. (2018). On the ‘association between two things’: the case of student surveys and classroom observations of teaching quality. *Educational Assessment, Evaluation and Accountability*. 30(4), 347-366.

van Es, E.A., & Sherin, M. G. (2008). Mathematics teachers' ‘learning to notice’ in the context of a video club. *Teaching and Teacher Education*, 24(2), 244-276.

Voigt-Antons, J.-N., Lehtonen, E., Palacios, A.P., Ali, D., Kojic, T. & Möller, S. (2020). Comparing emotional states induced by 360 videos via head-mounted display and computer screen. *2020 Twelfth International Conference on Quality of Multimedia Experience (QoMEX)*. IEEE, 1–6.

Vygotsky, L.S. (1987). *Mind in society: the development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wang R. & Wiesemes, R. (2012). Enabling and supporting remote classroom teaching observation: live video conferencing uses in initial teacher education. *Technology, Pedagogy and Education*, 21(3), 351-360.

Walshe, N. & Driver, P. (2019). Developing reflective trainee teacher practice with 360-degree video. *Teaching and Teacher Education*, 78, 97-105.

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C. & Schramm, H. (2007). A process model of the formation of spatial presence experiences. *Media Psychology*, 9, 493–525.

Wissmath, B., Weibel, D. & Groner, R. (2009). Dubbing or subtitling? Effects on spatial presence, transportation, flow, and enjoyment. *Journal of Media Psychology*, 21(3), 114-125.

Wu, W.-L., His, 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*. Published online DOI: 10.1080/10494820.2021.1878231

Yadav, S.K. (2011). Comparative study of pre-service teacher education programme at secondary stage in Bangladesh, India, Pakistan and Sri Lanka. *Educational Research and Reviews*, 6(22), 1046-1050.

Wolfenden, F. (2015). TESS-India OER: Collaborative practices to improve teacher education. *Indian Journal of Teacher Education,* 1(3), 13-29.

Wolfenden, F., Cross, S. & Henry, F. (2017). MOOC adaption and translation to improve equity in participation. *Journal of Learning for Development,* 4(2), 127-142.

Wolfenden, F. & Adinolfi, L. (2019). An exploration of agency in the localisation of open educational resources for teacher development. *Learning, Media and Technology*, 44(3), 327-344.

World Bank. (2018). *World development report 2018: Learning to realize education's promise.* Washington, DC: World Bank.

Wu, W.-H., Wu, Y.-C.J., Chen, C.-Y., Kao, H.-Y., Lin, C-H. & Huang, S.H. (2012). Review of trends from mobile learning studies: a meta-analysis. *Computers and Education*, 59(2), 817- 827.

Zhang, M., Lundeberg, M., Koehler, M.-J. & Eberhardt, J. (2011). Understanding affordances and challenges of three types of video for teacher professional development. *Teaching and Teacher Education,* 27(2), 454-462.