Australian Journal of Teacher Education

Volume 47 | Issue 3 Article 4

2022

Supporting Mathematics Pre-Service Teachers Reflection with 360degree Video and the Knowledge Quartet

Lisa O'Keeffe
University of South Australia

Bruce White
University of South Australia

Recommended Citation

O'Keeffe, L., & White, B. (2022). Supporting Mathematics Pre-Service Teachers Reflection with 360degree Video and the Knowledge Quartet. *Australian Journal of Teacher Education, 47*(3).
http://dx.doi.org/10.14221/ajte.2022v47n3.4

Supporting Mathematics Pre-Service Teachers Refection with 360degree Video and the Knowledge Quartet

Lisa O'Keeffe
Bruce White
University of South Australia

*Abstract**:** Secondary mathematics teaching is often characterised by teacher-led pedagogies centred on practice and memorising formula which can dominate incoming pre-service teachers' perceptions of mathematics teaching. Hence, creating opportunities for pre-service teachers (PSTs) - particularly those who have not experienced student-centered pedagogies – to see the power of alternative pedagogical approaches is crucial in the early experiences of their teacher training. This paper explores the potential of 360degree video recordings of micro teaching of PSTs to enhance initial reflections using the Knowledge Quartet. Drawing on four PSTs' 360degree video reflections using the Knowledge Quartet framework we unpack the different ways that 360degree video provides additional opportunities for understanding the wider classroom impact of PST pedagogical decision making. The findings suggest that together these two tools offer an effective platform for PSTs to trial teaching approaches and reflect on their practice in a structured way.*

Keywords: Mathematics pre-service teachers, 360degree video, reflective practice, the Knowledge Quartet

Introduction

Rowland, Turner, Thwaites and Huckstep (2009) highlight that PSTs tend to frequently apply traditional teacher-led instructional methods, focusing on teacher talk as the core of their practice. In an Australian context, Choppin (2011) reminds us that this is not isolated to PSTs but instead applies to any teacher with a negative perception of mathematics or reduced confidence in their own mathematical ability. Not surprisingly, curriculum reform in the countries such as USA, UK and Australia have called for a shift from this traditional style of mathematics classroom to a more active, constructivist classroom. Such a shift requires a focus on building students' understanding of mathematical concepts and a focus on inquiry based and active learning (Ebby, 1999). Despite this argument building from the nineties, Wright (2020, p. 2) reminds us that 'conventional teaching approaches persist, particularly in secondary schools (years 7–11), regardless of calls from the mathematics education community for … greater emphasis on reasoning skills and the development of conceptual understanding'. The reality, as flagged by Ball (1988) over thirty years ago, and Ebby (1999) again in the nineties, is that teachers are likely to teach mathematics in the way they were taught – taking an 'it worked for me' approach. Such work reminds us of the importance of creating a dissonance for (some) PSTs between the vision of mathematics

teaching they experienced as students and the vision of the mathematics teacher they would like to become.

Mayer et. al. (2017), as part of the Studying the Effectiveness of Teacher Education (SETE) project, found there was evidence to suggest initial teacher education was having an impact and producing effective beginning teachers but there was a need for improvement. More opportunities to teach were identified as being required and an important part of PSTs' development (Mayer et al., 2017). However, in-school teaching practice or placements can be problematic as they do not involve a common experience for reflection and PSTs in these contexts can be constrained in how they teach and in taking risks when they teach. Therefore, the use of micro-teaching to peers within their university coursework may be able to provide the opportunity for students to practice teaching in a more controlled environment and to reflect on this practice in a structured manner. In this paper we explore PST reflections of their teaching in a university context based on their reviewing of 360degree video of their own practice using prompts from the Knowledge Quartet framework (Rowland, Huckstep, & Thwaites, 2005).

Reflection for Teacher Development

Studies such as Mena, Sánchez and Tillema (2011) suggest teacher education uses reflection as a source of knowledge construction and hence as a means of bridging the gap between theory and practice. Both Ma (1999) and later Turner (2012) have highlighted the value of reflection for PSTs of mathematics to develop a better understanding of the importance of both their content and pedagogical knowledge, with studies such as Coffey (2014) highlighting the value of video reflection to promote critical reflection among PSTs. Not surprisingly, many professional development models also include a focus on reflection (Clarke, 2006) and multiple models and framework have been developed to support teachers in their reflective process (Mena, Sánchez and Tillema, 2011). One such framework is the Knowledge Quartet, with researchers such as Turner (2012) specifically identifying the role the Knowledge Quartet could play in supporting PSTs to develop as mathematics teachers.

The Knowledge Quartet was developed through video observations of how PSTs' mathematical knowledge played out in the classroom (Rowland, Huckstep, & Thwaites, 2005). Using a grounded theory approach Rowland et al. (2005) analysed the practices and behaviours of primary and middle PSTs. Initially, they identified eighteen categories which defined the pedagogical and subject content knowledge specific practices that they observed in their study. They refined these eighteen categories to the following four categories: foundation, transformation, connection and contingency (see Figure 1).

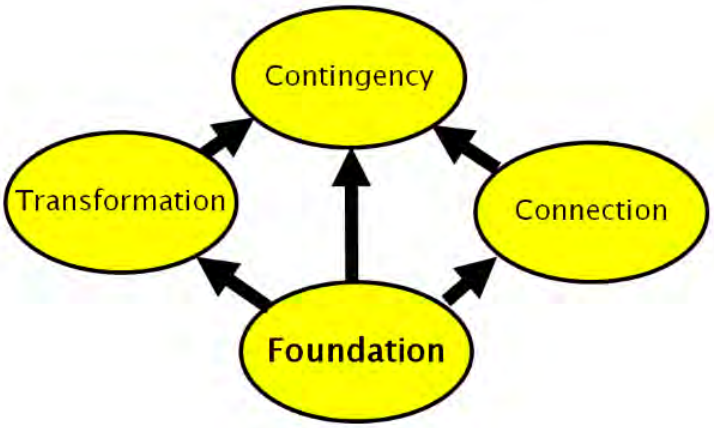

Figure 1: The Knowledge Quartet (Image source: http://www.knowledgequartet.org/)

Foundation is the first category and consists of PSTs' knowledge, beliefs and understanding that are useful for their classroom teaching. Key components of this category are knowledge and understanding of mathematics and the teaching and learning of mathematics, as well as beliefs regarding the nature of mathematical knowledge, the purpose of mathematics education, and how students learn mathematics. The second category of the Knowledge Quartet, transformation, concerns knowledge-in-action as demonstrated both in planning to teach and in the act of teaching itself. The category of transformation picks out the behaviour that is directed towards students which follows from teacher deliberation and judgement. Of particular importance is the PST's choice and use of examples. Connection, the third category, concerns the coherence of the planning or teaching displayed across an activity, lesson, or series of lessons. This reflects the thinking behind the choices made regarding connections within mathematics and an awareness of the relative cognitive demands of developing concepts and tasks. Contingency, the fourth and final category, concerns the awareness and ability to adapt to the students' ideas and adjust the lesson plan as required by what is happening in the classroom. The intention of the Knowledge Quartet framework was to 'identify and describe various ways in which mathematics content knowledge influenced the choices and actions of these novice teachers in their classrooms' (Rowland et al., 2005, p.258) and it was this awareness that we are keen to develop in our university students and to investigate in our research.

Video for Reflection

Video technology has been widely used in PST training and in-service teacher professional development since the late eighties (e.g. Gaudin and Chaliès, 2015; McCoy & Lynam, 2021). Gaudin and Chaliès (2015) discuss how video viewing, in teacher education, is a unique and potentially powerful tool. They indicated that while video use provides the opportunity to raise the quality of instruction, simply viewing video does not ensure development. Rather, substantive analysis of what the video shows is required. Tripp and Rich (2012) found teachers were more likely to recognise the need for change, and hence enact change in their practice, when using the video for reflection in comparison to using other courses of feedback such as personal reflection or peer observations. The teachers in their study identified that the video review and analysis process enabled them to: '(a) focus on key aspects of their teaching, (b) gain a new perspective, (c) trust the feedback they received, (d) feel accountable to change their practice, (e) remember to implement changes,

and (f) see their progress' (Tripp & Rich, 2012, p.737). Blomberg, Sherin, Renkl, Glogger and Seidel's (2014) work makes particular note of the potential role of video for developing PST reflective practices. One of the most useful opportunities provided by video reflection for PSTs (or in-service teachers) is the opportunity to 'step back' from the cognitive overload of 'in-the moment' decision making in practice and to become more analytical about what is going on (Rich & Hannafin, 2009; Balzaretti, Ciani, Cutting, O'Keeffe & White, 2019). Without the use of video, PSTs have to rely on their own recall of teaching episodes. Additionally, the early research into the field of video for self-review (e.g. Sherin & van Es, 2005) demonstrates that structured or focused reflection is most effective in facilitating the development of both pre-service and in-service teachers. The use of video viewing has the potential to create a collaborative space for teacher education (Youens, Smethem, & Sullivan, 2014) where traditional boundaries and knowledge are disrupted.

While video has been in use since the late eighties, 360degree video is a relatively new technology being used in teacher education and the affordances of this technology are just beginning to be identified. One of the main challenges of classroom video data collection is that decisions in regard to what to point a fixed video recorder at, and how many cameras to use, have to be made prior to recording. As discussed by Clarke (2006), every decision made reflects some form of interference by the researcher, which impacts on what data is gathered. In their study with PSTs in Ireland, McCoy & Lynam (2021, p. 929) used SWIVL technology (www.swivl.com)
which removes an element of prior decision-making which is required for a fixed camera, it still only enables a one-lens view of the enacted teaching. This focus is entirely on the teacher and as such may be assuming that the teacher is the focal point of a classroom and the centre-point of all learning.

In our work with PSTs we incorporate 360degree video recording, which produces video-recordings from an immersive 360degree perspective, providing the flexibility to record, view and analyse interactions from multiple view-points – those of the teacher and the learners. Being able to change the perspective of the video being viewed is useful (Walshe & Driver, 2015), and particularly useful is being able to see one's teaching from the perspective of the students in the class (Balzaretti et al., 2019). The use of 360degree video allows for a more immersive experience and facilitates PSTs noticing things and enhances their reflections through increased references to student/learner actions (Kosko, Ferdig, & Zolfaghari, 2020). Additionally, the 360degree video technology is unobtrusive. The cameras are small, handheld, portable devices and so less likely to result in 'performed' student interactions.

The Study

This study involved two cohorts of PSTs undertaking a curriculum course in Mathematics Education as part of their Master of Teaching (Secondary). The PSTs were in the first study period of the first year of their program and in general had no formal teaching experience. The first cohort, from 2018, comprised 33 PSTs, from which 24 PSTs volunteered to participate in our study and completed the Knowledge Quartet reflection. The second cohort, from 2019, comprised 46 PSTs. A total of 42 PSTs volunteered to participate in this study and completed the Knowledge Quartet reflection. Each year the PSTs come with a range of different backgrounds and experiences and there are a range of major areas of study including mathematics, science, health and physical education, science, humanities, languages and design and technology.

As part of the assessment in their first curriculum course in mathematics the PSTs, in assigned groups, prepare and engage in a micro-teaching experience with their peers as participants. This micro-teaching focuses on a particular aspect of mathematics which is aimed at a particular year level assigned to each group. This is their first formal attempt at teaching mathematics and follows a number of workshops focused on pedagogical approaches to mathematics. Following their micro-teaching (recorded using 360degree video cameras), the group engaged in dialogic feedback with their tutor and their peers before submitting a group written reflection (also part of assessment) on their micro-teaching. The 360degree video files were converted to the appropriate format to enable a viewer to drag the screen around to access a full 360degree view of the recording. The files were then shared with the PSTs on a platform designed to host 360degree video recordings. Each group had access to their own group videos only. The videos were hosted via a 360degree video web-based hosting platform, created as part of an ATN (Australian Tertiary Network) grant (O'Halloran et al., 2017) designed for viewing, annotating and analysing 360degree video. The software enables them to attach annotations directly to the video which are visible to others.

In 2018, the university students completed one formal presentation and reflection sequence. The video files were shared with the PSTs, in each teaching group, after they had completed their group reflection. The PSTs then reviewed and annotated their videos and completed an additional reflection using a web-based survey which included some questions related to their use of the 360degree video and a summary comment on what they noticed about their presence, interactions and explanations. In 2019, the PSTs undertook two separate presentations, one early in the study period followed by time to watch their video and reflect on it, and then another one towards the end of the study period to provide an opportunity for them to build on their learning after the first presentation. The PSTs completed a post-presentation survey and reflection for each micro-teaching presentation. The survey focused on identifying aspects of their practice which they learned more about with a particular focus on clarity, presence, board-work and interactions as teachers. The reflection after the first presentation in 2019 was centred on how they felt watching themselves teach and what they learned about themselves as teachers of mathematics from this process. The reflection following the second presentation in 2019, and at the end of the first and only reflection process in 2018, was guided by the Knowledge Quartet framework (Rowland, Huckstep and Thwaites, 2005).

In this paper we focus on the reflections which used the Knowledge Quartet as a structure to support and guide the PSTs to reflect on their own development. These reflections were based on reviewing their own teaching via the 360degree video recordings rather than on recalling what happened during the teaching, thus minimising the risk of discrepancy between recalled practices and actual practice (Sherin 2004). For each year, two case studies are provided to give a detailed insight into the ways in which the framework and 360degree video supported PSTs to engage more meaningfully in the reflective process.

The Case Study Participants

Two case studies from each cohort have been selected for this article. The key inclusion criteria were that the PSTs had to have completed a final reflection summary with a detailed response to the comments in relation to the Knowledge Quartet. Students were then grouped based on 'like' criteria beginning with their major area of learning in the teaching degree; one group with mathematics as a major, the other group having a non-mathematics major. From each group one student was selected at random from the 2018 cohort and then

'like' criteria (course grade and GPA range) were again used to select 2019 participants so that the 2018 and 2019 case study participants presented here could be considered similar.

Table 1 provides an overview of the four case study participants who are the focus of this article. The table provides the PSTs' areas of specialism, their final course grade in the course in which this study took place, as well as their GPA. The inclusion of course grade and GPA is to provide an indication of how well the students are tracking in the first year of their program of study and also to show the academic similarities between the case study participants. As evident in Table 1, each of the PSTs was academically strong and had transitioned well, either from their undergraduate degree or back to study, into the Master of Teaching Program. One of the PSTs, Ava, had considerable experience teaching mathematics in non-school contexts but did not have a formal secondary teaching qualification.

YEAR	PST (Pseudonyms)	Major area of study	Minor area of Study	GPA*	Course Grade
2018	Claire	Mathematics	Psychology	6.10	D
2018	Beth	Health and Physical Education	Mathematics	5.42	C
2019	Ava	Mathematics	Mathematics	7	HD
2019	Denise	Health and Physical Education	Mathematics	5.25	C

* GPA at the end of the first study period. The course in which this study is taken is part of this study first period. At this university the students can obtain a maximum grade point average (GPA) of 7

Table 1: Case study participants

Data Analysis

An inductive deductive approach, as described by Azungah (2018), was applied in the analysis of the reflection data for each participant. Such an approach uses a structure or framework to guide the coding process (deductive). Following this, inductive coding was applied by both authors independently. This involved reading and re-reading the data to identify and understand the participant experiences as presented in the reflections and as relevant to the research objectives (Thomas, 2006). This initial coding was guided by two key foci: (1) appropriateness, that is, the reflection addressed the correct dimension of the Knowledge Quartet (for example a reflection included for the foundation category actually focused on addressing the foundation dimension), and (2) depth of reflection. Both authors have a number of years' experience working in PST education and hence have experience reading and reviewing PST reflection. The second coding, according to the criterion of depth of reflection, was refined by assessing whether there was a focus on describing the teaching experience only with minimal reflection, describing the teaching experience with some reflection throughout, or reflecting on the teaching experience with reference to examples from practice. This was an iterative process guided deductively by the Knowledge Quartet (Rowland, Huckstep, & Thwaites, 2005) and inductively from the emerging themes from within the data in each category. Following independent coding the authors then collaborated to finalise the analysis. Where there were differences in coding these were addressed through discussion and then instances were reclassified accordingly. The students' comments are reproduced in Tables 2, 3 and 4 in the following discussion to facilitate research transparency.

Discussion of Results: Case Study Reflections

A limitation of the 2018 data is the lack of opportunity provided for PSTs to learn from their experience and 'try-again'. To address this, the 2019 cohort had the opportunity to practice their teaching, watch the recorded 360degree video, reflect on their teaching and then begin a new phase of practice. This enabled them to learn from their feedback and reflections on the initial practice of teaching. The 360degree videos also enabled PSTs to review their practice from different perspectives. This is evident in the detail they provided in the post video reflections in comparison to their debrief and post-teaching reflection in-class after their initial presentation. In their initial post presentation reflections, the 2019 PSTs tended to provide superficial reflections, focusing on broad sweeping summaries rather than the detailed of what worked and why. In contrast, after their second presentations the 2019 PSTs drew on the videos to reflect on their actual teaching, thinking about how they enacted their planning, how they did/didn't respond to in the moment challenges and how their students engaged with the lesson.

Foundation

The foundation dimension of the Knowledge Quartet is intended to encourage teachers of mathematics to reflect on their own content knowledge and how they use this content, in conjunction with their own beliefs and perspectives of mathematics education, to inform their approach to teaching.

	Extracts from completed reflections in PSTs' own words
CLAIRE (2018)	I feel as though I have a sound understanding of mathematical concepts myself. I made the mistake of thinking that the people I was teaching to also had a similar level of understanding. I felt, that during our activities they demonstrated that they did not have a strong basis on the content we were presenting. This made our tasks somewhat challenging and as such I found myself trying to re-teach content to my fellow PSTs instead of just focusing on the teaching techniques we were trying to discuss. Even if they did not have this content knowledge, I should not have allowed it to distract me from my main purpose.
BETH (2018)	My undergraduate degree predominantly focused on health and physical activity. I only participated in four mathematics courses, and in my opinion I have limited knowledge of the content. I am not overly confident with teaching mathematics and the reasoning behind why it is taught. This was evident in the presentation my group conducted. I was not in-depth with why we were teaching the different activities of two-step chance and it something that I need to improve on.
AVA (2019)	. From watching the videos and reviewing the peer feedback, I think my beliefs differ from many of my peers. I believe in student-centred learning, and so am comfortable with launching an activity without disclosing the topic, and with asking questions (about fairness) without initially giving too much scaffolding, because there will be opportunities to consolidate thinking later (although, in this instance, I missed doing this at the conclusion of the lesson).
DENISE (2019)	Within our presentation we have … the ability to inform strategies and pedagogical choices in a fundamental way. By this I mean, we have a rational or reasoned approach to make certain decisions, which is relying on habit or imitation. Being PSTs, we are learning a multitude of ways to teach pedagogies. We are at a stage where we can use different approaches to see what learning style is best for us, but this will vary depending each class we are teaching.

Table 2. Knowledge Quartet Reflection: Foundation

From Table 2 it is evident the PSTs in our case studies were able to confidently reflect on the content knowledge aspect of the foundation category of the Knowledge Quartet (see

Figure 1). Their reflection on how to use that content was related to their initial degree of study, with the students who had greater content knowledge – in this case those with a degree in mathematics – being better able to reflect on the use of that content in teaching. For example, Claire and Ava, who each have mathematics as their major area of study, make reference to their background in mathematics. Ava has the strongest mathematical background, and she makes direct reference to a particular approach to teaching mathematics drawing on evidence of this in her video reflection. Claire on the other hand, although confident in her own content knowledge, appears to be placing some blame for the issues in her micro-teaching session on her participants not having good enough content knowledge. This suggests a lack of or understanding about her role in engaging participants in the learning experience, a point which she did not recognise. Beth's main area of study is not mathematics and she commented on how she is less sure about her own content knowledge. Beth's video reflection indicated an awareness of content issues in her presentation. Denise makes the most connection back to the theory in her reflection.

From a teacher educator point of view this type of connection back to theory is reassuring; to unpack and make sense of her learning and experiences she is drawing on the best source of 'evidence' she has at this early stage in her teaching program – the literature. She identifies that at her stage in her program she should be trying things out and seeing what works. However, Denise also lacked confidence in her content knowledge and her reflection tended to focus more on how she presented herself rather than her knowledge, for example including specifics such as: 'I projected my voice … I was confident… my explanations were clear'... Following the video reflection though, Denise decided she should focus on planning to ensure time wasn't wasted on aspects of the lesson that weren't the primary focus and that she should have more support materials at hand. The non-mathematics major PSTs all made direct refence to their planning, as did Ava, without connecting this element of their reflection to their video explicitly, whereas Ava did make this connection.

The data indicates the PSTs are reflecting honestly and realistically in regard to the foundation category of the Knowledge Quartet. While only one of the PSTs make direct reference to the use of the 360degree video in her reflection, all PSTs have used the 360degree video and reviewed their practice before completing their reflection. This component of the Knowledge Quartet focused on the teacher and their knowledge and hence the advantages afforded by 360degree are not required for this component.

Transformation and Connection

The transformation category of the Knowledge Quartet is useful in supporting PSTs to reflect on how best to present and explain different aspects of mathematics. Shulman (1986, p.9) refers to this as the 'presentation of ideas to learners in the form of analogies, illustrations, examples, explanations and demonstrations'. In contrast, the category of connection relates to the coherence of a plan and its enactment in the classroom as an episode, a lesson or a unit or work (Rowland, Huckstep, & Thwaites, 2005). It is important for PSTs to reflect on how and why they have structured things in particular ways and what impact their decisions have on student learning.

	Extracts from completed reflections in PST's own words
CLAIRE (2018)	*Transformation:* I feel as though our activities were appropriate and that our lesson plan was quite clear in our intention. Unfortunately, we did not do a very good job of translating our planning and depth of understanding to the context of our pre-service classroom. *Connection:* We had sequenced our tasks well but because we failed to successfully transform our planning and understanding to the classroom, we did not allow for the connections we had tried to make to be effectively conveyed to the group.
BETH (2018)	*Transformation:* Our planning for a year 9 probability class looked good on paper, however we did not plan according to the designated task. I believe the activities, if conducted well to year 9s, would be interesting due to their interactive nature and would assist with the learning of two-step chance. The selected activities would allow the PSTs to understand and remember the concept of two-step chance by doing rather than just listening and doing bookwork. *Connection:* If we were teaching a year 9 mathematics class, the sequencing of tasks selected were appropriate for the topic. We began with prior knowledge of probability, one-step chance and then two-step chance with different variations. On the other hand, for a professional development class we did need to go through each individual task but more-so provide resources and details on how different two-step chance activities can be implemented into the classroom.
AVA (2019)	*Transformation:* My planning is strongly influenced by considering how students will best learn mathematics. For the planned lesson, it was why we decided to use an activity to give students a good feel for the problem, then stage the interpretation of results in two parts (analyse own results of playing the game; analyse the class results). We wanted to spend time on building intuition about the game (including the possibility that intuition would change over time) before introducing the calculations of theoretical probabilities. My interpretation is that /transformation/ is also about predicting stumbling blocks that students might encounter. We included enabling questions in our lesson plan that anticipated some of these. For example: 'Can you think of a combination of two cards that is not in your table?' *Connection:* This concerns coherence and sequencing within and between lessons, including ordering of activities. It also includes managing the mathematical discourse of the classroom to make connections between students' ideas. In relation to planning: we gave strong consideration to the sequencing of events, and how the mathematical development should unfold (intuitive feel for the game, experimental probabilities, the need for calculating theoretical probabilities). In relation to watching the video: I noticed evidence from all of us in connecting students' ideas to the topic, and in using students' ideas to help in the development of the lesson.
DENISE (2019)	*Transformation:* Whilst understanding the content is essential, I needed to practice performing my lesson more to ensure I knew the questions I wanted to ask prior to presenting. Not only do I need to understand the content, but I need to understand it in a way that will allow me to help a student learn. This means I need to be able to show the concepts in various ways, such as illustrations, explanations, examples, demonstrations, etc. (Shulman, 1986, p.9). This shows I must be able to understand and present trigonometric ratios is various ways to ensure learning occurs, e.g. picture of a building, relating to real life contexts. *Connection:* To ensure connections are made, it was essential that we implemented a rundown of Pythagoras at the beginning of the lesson to allow for cognitive connections to be engaged. When transferring into trigonometric ratios students were able to make the connection, as a result more clearly understand new concepts. Sequencing topics of instruction within and between lessons, of tasks and exercises is essential to not only make structural connections, but also relative cognitive connects among different topics and tasks.

Table 3. Knowledge Quartet Reflection: Transformation and Connection

There was significant overlap between the reflections made in relation to the transformation and connection categories and hence this data has been combined into one table (see Table 3). These reflections suggest the 360degree video of their micro-teaching supported these PSTs to make connections between aspects of the Knowledge Quartet framework. There was an emerging understanding that mathematics teaching is much more than the transmission of one solution/method, with these emerging teachers beginning to see that mathematics is about making the connections between different elements of

mathematics, between different perspectives, and across other subject areas as well as everyday life (Smith, 2004). This indicates two key points relevant to both case studies: (1) a naivety about the plan – 'I planned it therefore…', but also a beginning awareness of (2) the importance of strong mathematical content knowledge for teaching (Hill, Rowan, & Ball, 2005). However, there was some variance between where they were in terms of this level of understanding. For example, Ava knew they had a good learning experience plan and was aware of the importance of enacting this plan well and being able to articulate why it worked well. Similarly, Claire was aware that they had a good plan but that they didn't enact it very well.

While Beth felt that her group's planned activities were appropriate, she wasn't connecting this with her earlier reflection that they didn't think their activities through (for example, there was no awareness of the need for alternative ways of explaining/questioning). Both Denise and Beth referred to the need to be more aware of how to enact their planning, with Denise suggesting she needed to do some more 'practice' beforehand. Their reflections on this however, lack depth. There was no understanding of what they might have done to address some of these issues, other than limited suggestions such as it 'would have been good to draw on the statistical reports obtained from the Kahoot quiz (online quiz platform for teaching and learning, often used in mathematics)' and, 'in the future a clear and concise description with demonstrations of the task will promote further learning'. They do not provide any indication of why this would be better, or why it had not been included to begin with.

The affordances of 360degree video becomes more apparent in the transformation and contingency stages of reflection. As discussed above, the PST reflections demonstrate their emerging understanding of the complexity of teaching mathematics. This is an important stage of development for PSTs of mathematics as sometimes PSTs' own experience as students of mathematics are characterised by teacher-led pedagogies that are centred on practice and memorising formula. Given that they themselves have been successful in this type of teaching environment they often find it difficult to understand why others might not succeed in such an environment. The use of 360degree video for reflection allows them to 'step-back' (Rich & Hannafin, 2009; Balzaretti et al., 2019) and take time to process what unfolded in their lesson, why it unfolded as it did and how this was perceived by the student/ participants. For example, Ava describes when reviewing the video she gained a better understanding of the value of using the students' ideas and input and how this in turn shaped the development of their lesson. The ability to pan around and see the learning experience as it unfolds from multiple perspectives provides new insights for these PSTs to better understand their own decision making and the impact of these decisions; beginning to understand that their decision-making shapes their students' learning experience.

Contingency

Planning in mathematics includes teachers planning for the possible questions, queries and reactions that might come up through the lesson or student learning experience. Contingency relates to how one has done this in order to then think on one's feet and respond, in the moment, to the questions or suggestions that students might have (Rowland, Huckstep, & Thwaites, 2005).

	Extracts from completed reflections in PSTs' own words
CLAIRE (2018)	We were faced with another problem when the groups didn't grasp the tasks due to a lack of content knowledge, I tried to continue on through the presentation but I should have stayed with the difficult task and explained it as explicitly as possible so that that time wasn't wasted. I should have trusted in my own knowledge and ability, transformed the task through explicit teaching, so that the groups were able to make the connections they were expected to make through the activity. (Basically I shouldn't have doubted myself and just stuck to my guns)
BETH (2018)	Seeing as we prepared predominantly for a year 9 probability class and what to teach, we had to think on the spot throughout a majority of the presentation to amend it to the professional development criteria. This was actually quite difficult and really accentuated the need for planning as a PST. At times the class would comment on some things that we could not elaborate on as we do not have much experience at on-the-spot teaching.
AVA (2019)	This is about responding to students' ideas 'thinking on one's feet' and deviating from the plan if necessary. When watching the video, I noticed that this describes the fluid way in which I was able to draw on and incorporate students' responses in the whole-class discussion. As is mentioned in the reading, "responding" moves ... are some of the most difficult tactics for newly qualified teachers to master', and so I am at an advantage here! Of course, it's also much easier (and perhaps it's not really contingency action) if, in planning for 'transformation', one has thought through the possible responses that students might give. We gave this careful thought in our lesson plan, for example, 'students might think it is fair because ...', 'students might think it is unfair because ...'. However, I also noticed in my small group interaction (with M, S and D) that I needed to work a bit harder/longer to understand M's line of thinking before I would be able to meaningfully respond to it to propel his thinking forward.
DENISE (2019)	Whilst teachers' actions can be planned for, students' responses cannot. It's essential that as a teacher I am able to answer students' questions to facilitate learning. This occurred within our presentation when we took a short cut when demonstrating an example on the board, thus students were immediately lost. In this instance we then went back to where we were prior to taking the short cut and completed the process fully then explained when this short cut may be taken.

Table 4. Knowledge Quartet Reflection: Contingency

Table 4 presents the case study reflections on the framework category of contingency. It is important to note that it is unlikely that the participants, given their stage of study, would be ready to always respond to 'in the moment' student questions, reactions and or misconceptions. However, the combination of the 360degree video and the structure afforded by the contingency prompt, should allow the PSTs to reflect on where these arose and how they could deal with them. In practice the PSTs were focused more on enacting their planned lessons, rather being able to read their participants and respond to their learning needs in the moment. The reflections in Table 4 provide an insight into the different ways this has been understood by the PSTs and gives an indication of how ready they are to move their reflection from themselves and their teaching practice to their role in facilitating the learning of others. For example, Claire indicates that the issue with group size (number of students in the session) impacted on their planning and that this 'negatively impacted on how effectively the groups were able to complete the task', following this she noted that the students didn't have the content knowledge to complete the task. Here the 'issue' was with things outside of her control and there seemed to be a sense of frustration with this. In the teaching session Claire and her peers decided to skip over this complexity without addressing it. However, reviewing the 360degree video created an opportunity for Claire to reflect back on what this meant for their students in that learning experience. This is clear in her statement that: 'I should have trusted in my own knowledge and ability, transformed the task through explicit teaching, so that the groups were able to make the connections they were expected to make through the activity'.

Not surprisingly, the PSTs' ability to question and respond to questions and/or challenging situations around content was not always recognised by the PSTs. However, their reflections indicate that through using the 360degree video they were able to look back on their own practice and consider what they could have/should have done differently. For example, Beth commented that: 'At times the class would comment on some things that we could not elaborate on as we do not have much experience at on-the-spot teaching'. Ava's reflection makes explicit reference to her use of the 360degree video and it is evident that she is able to look at her teaching practice from the students' perspective and comment on this. Additionally, Ava reflected on the quality of student-to-student interaction, noting one of her shortcomings in her interpretation of the students' thinking.

Of importance here is that, despite Ava's experience, she identified that it was the 360degree video that enabled her to realise that she did not do this during the teaching session. This suggests that even with significant teaching experience 360degree video creates a greater opportunity to understand and reflect on enacted teaching. This adds to Tripp and Rich's (2012) finding that teachers are more likely to recognise the need for and enact change in their practice when using the video for reflection. In their work they are referring to fixed video which requires prior decisions about what to point a fixed video recorder at and how many cameras to use. As discussed by Clarke (2006), each of these prior decisions reflects some form of interference in the teaching/reflection process. The 360degree camera, however, creates an opportunity for changing perspective at the review and reflection stage and hence provides a richer environment on which teachers of all stages of experience can reflect. Claire, Beth and Denise all make explicit reference to some form of realisation they came to as a result of reviewing their 360degree video. For example, Claire confirmed that from her participants' reactions she should have responded differently to the participants and made more connections between the concepts and the learning activity. Similarly, Denise's review of the video highlighted, for her, the impact of the teachers taking a 'short cut when demonstrating an example on the board'.

Conclusion

This paper explored the role of 360degree video as tool for enabling greater depth of reflection among PSTs when used in conjunction with a guiding framework for reflection. While the role of video for teacher and PST reflection has been well established, the potential of 360degree video is not as well developed. In previous work, the authors have identified that the major affordance of 360degree video is that it creates the opportunity to pan around the screen and review one's practice from multiple perspectives (Balzaretti et al., 2019; O'Keeffe, Rosa, Vannini & White, 2020). The above examples and extracts from PST reflections provide evidence to support the value of 360degree video as a tool for facilitating PST reflection on teaching practice. It is important to note that these students completed this reflection in either week 9,10 or 11 of their first course in their Master of Teaching program. So, while they are relatively experienced as students (each having previously completed an undergraduate degree), many of them have had little to no interactions with teaching in any capacity other than as a school or university student themselves. Evidence to support this is scattered throughout the student reflections, in statements such as: 'It's not easy to watch yourself, but I definitely feel as though I learned something about how I present myself in the classroom as a result' (Claire). Similar findings have previously been reported in Balzaretti et al., (2019). Of significance to this article is the way in which the students were able to draw on specific examples of their practice, reflecting on themselves as teachers and from the perspectives of the learners. This was made possible by 360degree video-recordings which

enabled the PSTs to focus their reflection on the class and the learning environment as a whole rather than just themselves as teachers/teaching.

The authors have been working with students in this course for a number of years and have noticed a marked improvement in the quality and depth of reflection that PSTs are producing within such a short timeframe; they move from a focus solely on describing what happened to looking to understand how to best respond to particular situations/interactions. Prior to our use of 360degree video in our classes, PST reflections often focused more on describing what they did well and/or an attempt at recalling things they may need to improve on. However, it is in relation to the latter that most PSTs struggled. For example, identifying how the way in which they responded to their students either supported learning or added confusion, how they actually distributed their questions among the cohort and worked with student responses in ways that did/didn't elicit more student thinking. In short, it is understanding what might need to be improved and why, and exploring how to go about this, which is key to their development as effective teachers of mathematics. As evidenced in the Knowledge Quartet reflections from the case studies discussed, we can see that these PSTs were able to move beyond descriptive reflection in most cases. Within the reflections reported here there is also a genuine attempt to start to think about how one's teaching practices may be responded to by student learners and how these practices connect with one's understandings of initial theory being learned about in this and other pre-service courses. This shift towards more in-depth reflection is a notable step, particularly given the early stage these PSTs are in their teacher training program. In conjunction with video recordings, the Knowledge Quartet framework provided a useful structure to scaffold this shift. It enabled the PSTs to build from the foundation to contingency categories of the framework and enabled them to focus on reflections about pedagogy rather than just describe the content or sequence of a lesson. In many ways it helped to focus the PSTs to move beyond descriptive to more critical reflection aided by the opportunity for repeated re-viewing of video of their own and their peers' initial forays into teaching practice.

References

Azungah, T. (2018). Qualitative research: Deductive and inductive approaches to data analysis. *Qualitative Research Journal,* 18(4), 383–400. https://doi.org/10.1108/QRJ-D-18-00035

Ball, D.L. (1988). Unlearning to teach mathematics. *For the Learning of Mathematics*, 8(1), 40-48.

Balzarettia, N., Ciani, A., Cutting C., O'Keeffe, L. & White, B. (2019). Unpacking the potential of 360degree video to support preservice teacher development. *Research on Education and Media*, 11(1), 63-69. https://doi.org/10.2478/rem-2019-0009

Blomberg, G., Sherin, M. G., Renkl, A., Glogger, I., & Seidel, T. (2014). Understanding video as a tool for teacher education: Investigating instructional strategies to promote reflection. *Instructional Science,*42(3), 443–463. https://doi.org/10.1007/s11251-013-9281-6

Choppin, J. (2011). The role of local theories: Teacher knowledge and its impact on engaging students with challenging tasks. *Mathematics Education Research Journal*, 23(1), 5-25 https://doi.org/10.1007/s13394-011-0001-8

Clarke, A. 2006. The nature of substance of cooperating teacher reflection. *Teaching and Teacher Education,* 22, 910–21. https://doi.org/10.1016/j.tate.2006.04.039

Coffey, A. M. (2014). Using video to develop kkills in reflection in teacher education students. *Australian Journal of Teacher Education,* 39(9), 86-97. https://doi.org/10.14221/ajte.2014v39n9.7

Ebby, C. (1999), Learning to teach mathematics differently: The interaction between coursework and fieldwork for PSTs. *Journal of Mathematics Teacher Education,* 3(1), 69-97. https://doi.org/10.1023/A:1009969527157

Gaudin, C., & Chaliès, S. (2015). Video viewing in teacher education and professional development: A literature review. *Educational research review,* 16, 41-67. https://doi.org/10.1016/j.edurev.2015.06.001

Hill, H.C., Rowan B. & Ball, D.L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *America Educational Research Journal,* 42, 371–406. https://doi.org/10.3102/00028312042002371

Kosko, K. W., Ferdig, R. E., & Zolfaghari, M. (2020). Preservice teachers' professional noticing when viewing standard and 360 video. *Journal of Teacher Education*, 72(3), 284-297. https://doi.org/10.1177/0022487120939544

Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. London: Lawrence Erlbaum. https://doi.org/10.4324/9781410602589

Mayer, D., Dixon, M., Kline, J., Kostogriz, A., Moss, J., Rowan, L., Walker-Gibbs, B. and White, S., (2017). *Studying the effectiveness of teacher education: Early career teachers in diverse settings*. Singapore, Springer. https://doi.org/10.1007/978-981-10-3929-4

McCoy, S. Lynam, A. (2021). Video-based self-reflection among PSTs in Ireland: A qualitative study. *Education and Information Technologies*, 26, 921–944. https://doi.org/10.1007/s10639-020-10299-w

Mena M., J., Sanchez, E., & Tillema, H. H. (2011). Promoting teacher reflection: What is said to be done. *Journal of Education for Teaching: International Research and Pedagogy,* 37, 21–36.m https://doi.org/10.1080/02607476.2011.538269

O'Halloran, K., Tan, S., Sheffield, R., Mallet, D., Aubusson, P., Berry, A. & O'Keeffe, L. (2018). *Encouraging and mapping student engagement through 360degree video annotation and data analytics*. Final Report, Curtin University.

O'Keeffe, L., Roas, A., Vannini, I. & White, B. (2020). Promote informal formative assessment practices in higher education: The potential of video analysis as a training tool. *Journal per la formazione in rete,* 20(1), 43-61.

Rich, P.J. & Hannafin, M. (2009). Video annotation tools: Technologies to scaffold, structure, and transform teacher reflection. *Journal of Teacher Education,* 60(1), pp.52-67. https://doi.org/10.1177/0022487108328486

Rowland, T, Huckstep, P, Thwaites, A. (2005). Elementary teachers' mathematics subject knowledge: the Knowledge Quartet and the case of Naomi. *Journal of Mathematics Teacher Education,* 8, 255-281. https://doi.org/10.1007/s10857-005-0853-5

Rowland, T., Turner, F., Thwaites, A., & Huckstep, P. (2009). *Developing primary mathematics teaching: Reflecting on practice with the Knowledge Quartet*. London, Sage. https://doi.org/10.4135/9781446279571

Sherin, M. & Van Es, E.A. (2005), Using video to support teachers' ability to notice classroom interactions. *Journal of technology and teacher education*, 13(3), pp.475-491.

Shulman, L. (1986). Those who understand, knowledge growth in teaching. *Educational Researcher,* 15(2), 4–14. https://doi.org/10.3102/0013189X015002004

Smith A. (2004). *Making mathematics count – the report of Professor Adrian Smith's inquiry into post-14 mathematics education.* London: The Stationary Office Limited.

Thomas, D.R. (2006). A general inductive approach for analysing qualitative evaluation data, *American Journal of Evaluation*, 27 (2), 237-246. https://doi.org/10.1177/1098214005283748

Turner, F. (2012). Using the Knowledge Quartet to develop mathematics content knowledge: the role of reflection on professional development. *Research in Mathematics Education*, 14(3), 253-271. https://doi.org/10.1080/14794802.2012.734972

Tripp, T.R. & Rich, P.J. (2012). The influence of video analysis on the process of teacher change. *Teaching and teacher education*, 28(5), pp.728-739. https://doi.org/10.1016/j.tate.2012.01.011

Youens, B., Smethem, L., & Sullivan, S. (2014). Promoting collaborative practice and reciprocity in initial teacher education: Realising a "Dialogic space" through video capture analysis. *Journal of Education for Teaching: International Research and Pedagogy*, 40(2), 101-113. https://doi.org/10.1080/02607476.2013.871163

Walshe, N & Driver, P. (2019). Developing reflective trainee teacher practice with 360degree video. *Teaching and Teacher Education,* 78, 97-105. https://doi.org/10.1016/j.tate.2018.11.009

Wright, P. (2020). Transforming mathematics classroom practice through participatory action research. *Journal of Mathematics Teacher Education*. https://doi.org/10.1007/s10857-019-09452-1.