Innovating methodology through international collaboration: Expanding the use of video analysis for understanding learning designs

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Apporti metodologici innovativi attraverso la collaborazione internazionale: l'uso della video analisi per comprendere la progettazione didattica

The purpose of this paper is to propose new directions for research in the use of video analysis to improve teaching and learning design in mathematics. The research directions have been developed through an international collaboration involving researchers from Italy and Australia. The paper includes an outline of these context and the different drivers for research before presenting providing a literature review to support future methodological innovation.

Keywords: video analysis, teachers professionalism, learning design, innovating methodology, internationalization, Mathematics teaching

L'articolo descrive e approfondisce le nuove direzioni di ricerca in ambito educativo attraverso l'uso della videoanalisi per migliorare la progettazione dei processi di insegnamento-apprendimento della matematica. Le direzioni di ricerca sono state sviluppate attraverso una collaborazione internazionale che ha coinvolto ricercatori italiani e australiani. L'articolo illustra una panoramica dei diversi contesti di ricerca e delinea un'ampia trattazione della letteratura di ambito come quadro teorico d riferimento della proposta metodologica innovativa.

Parole chiave: videoanalisi, professionalità degli insegnanti, progettazione didattica, innovazione metodologica e sperimentazione, internazionalizzazione della ricerca, didattica della matematica

L'introduzione e i §§ 2, 3 e 5 sono stati scritti da Simon Leonard; il § 2.1 e 4.1 da Nicoletta Balzaretti; il § 2.2 da Paul Unsworth; i §§ 3, 3.1, 3.2 da Ira Vannini; i §§ 3.3, 4, 4.1, 4.2 da Lisa Lim e Paul Unsworth. Tutto l'impianto del contributo e le conclusioni sono frutto di una riflessione comune tra tutti gli Autori.

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1. Introduction

By bringing researchers together to look at similar problems from perspectives shaped by different contexts, international collaborations provide opportunities to innovate in educational research. This paper reports on the first steps in one such innovative collaboration, a partnership between the University of Bologna, Italy (UNIBO) and the University of South Australia, Australia (UNISA). Drawn together by a common interest in the use of video analysis to improve mathematics teaching and learning design, these first steps have engaged the researchers in the partnership in an analysis of the differences and similarities of the Italian and Australian contexts. This analysis, discussed in the first section of this paper, has provided new insights into the work in both countries. In turn this has led to a new literature review, the reporting of which forms the bulk of the present paper. The paper will conclude by outlining innovative directions for new research based on the understandings built by our joint analysis of the literature.

2. Comparisons

With the improvement of mathematics teachers and learning design as a common background, the UNIBO and UNISA research group came together in 2018 with support from the Erasmus+ mobility program of the European Union. The initial intent was to draw on the joint expertise of the group in the use of video analysis to develop new research projects to fully utilise the affordances of the Samsung SMARTSchool (SSS), a purpose-built facility at UNISA designed to support the video analysis of classroom activity. The UNIBO researchers brought to their Australian partners rich experience in using video as a tool to foster in-service mathematics teachers' professional development, gained through participation in the FAMT&L European Project (Ferretti, Michael-Chrysanthou & Vannini, 2018). Early engagement across the new partnership quickly revealed that the exchange would be more extensive than a swapping of technical protocols. Rather, the exchange has led to extensive discussions of the respective contexts, which we outline below.

2.1 *The Italian/European Context: the FAMT&L project*

The FAMT&L (Formative Assessment in Mathematics for Teaching and Learning) project was funded under the European Commission's Lifelong Learning program in 2013 and involved five European countries (Italy, Netherland, France, Switzerland and Cyprus). The processes of learning and teaching mathematics and science are a fundamental component of school activities, preliminary to most of the skills that are significant for life and necessary for citizenship education. However, despite

the commitment of researchers and teachers, the crisis in teaching and learning mathematics in some European countries is becoming widespread (OCSE, 2013). The principal aim was to make a focus on the practices of formative assessment of the mathematics' teachers; to gather information on training and learning needs of teachers; to collect and to analyse data on the formative assessment of the mathematics' teachers in the school contexts of the different partner countries involved. The main goal was to develop objective observational measures of classroom instruction to serve as quantitative indicators of teaching practices in formative assessment. It involved, from a methodological point of view, having the same methodological approach to collect the data, to use the same process to reduce video data, to exploit the data in the same way. That means to provide standardized procedures for using the camera and standardized procedures for analysing videos.

The results of FAMT&L project were related to the realization of a training model (through e-learning) for school math teachers (which can be applied in service and in pre-service training) that has improved teachers' skills: in the field of educational planning and evaluation (both formative and summative assessment, evaluation for learning); and in teaching mathematics in the direction of problem-based learning processes. In this project, video analysis technologies thus serve as a powerful means to activate teachers' professional learning to create awareness, understanding and application of the role that formative assessment plays in mathematics teaching and learning.

2.2 *The Australian context*

As with many OECD countries, Australia's impetus for improving mathematics teaching is informed by declining PISA rankings and relatively static performances in the Trends in Mathematics and Science Study(s) (Thomson, Hillman et al., 2012; Thomson, Wernert et al., 2017) and national testing regimes (Australian Curriculum, Assessment and Reporting Authority, 2018).

Arguably, if there is to be authentic change in mathematics teaching, pre-service teacher education needs to be a significant point for leverage. The main role of pre-service mathematics education is to ensure that graduate teachers know their subject matter knowledge and have an informed perspective of contemporary mathematics pedagogy and practice, and are able to demonstrate this when teaching (Sullivan 2011; Livy, Vale et al., 2016). As Sullivan argues, particular attention needs to be directed at educators gaining richer understandings of the goals and principles that constitute effective teaching and learning of mathematics, in order to develop in learners, not only conceptual understanding and procedural fluency, but also actions of strategic competence and adaptive reasoning. These views have become increasingly pertinent in view of political debates positioning many graduate teachers as under equipped to teach mathematics (House of Representatives Standing Committee on Employment, Education and Training, 2017).

In an attempt to address this, the Australian Government in conjunction with the Australian Council for Educational Research (ACER) recently introduced a Literacy and Numeracy Test for Initial Teacher Education Students (LANTITE), which all graduate teachers must pass to qualify for their degree. According to ACER (2018), the test is designed to assess initial teacher education students' literacy and numeracy skills to ensure they 'are equipped to meet the demands of teaching and assist higher education providers, teacher employers and the general public to have confidence in the skills of graduating teachers'.

However, while the LANTITE may lend statistical weight to pre-service teachers' mathematical proficiency, evidence of improvement in mathematics teaching also requires comprehensive qualitative support. Teaching to Australia's diverse learner contexts requires teachers to draw on much deeper conceptual, socio-cultural and pedagogical knowledge, which includes rehearsal of teaching into practice (Sullivan, 2011; Owen, 2014; Groundwater-Smith, & Ewing et al., 2015). Pre-service educators need to develop deep professional expertise to effectively plan, implement and assess well-designed mathematics teaching and learning programs (Macmillan, 2009; Van de Walle, Karp et al., 2015; Reys, Lindquist et al., 2017).

Pre-service teacher mathematics education programs thus have a responsibility to embed relevant theoretical and evidence-based approaches into mathematics education course design and delivery. In this space, our professional interest as mathematics education teacher-researchers gravitates to exploring how video analysis technologies contribute to pre-service teacher's professional growth and vision. Of particular interest is investigation of the coupling of video analysis technologies within a learning design approach that positions learning theory and pedagogical reasoning alternately rehearsed into practice (Elliot, Sweeney et al., 2009; Lockyer, Heathcote et al., 2013).

The next section will provide a review of literature that captures an overview of video analysis technologies and their application in educational research and teacher professional development. Additionally, the review brings attention to new innovative elements in video analysis including video annotation and video analytic technologies.

3. Literature Review

The discussion of context briefly reported above highlighted to our research group the need to engage in an extensive re-examination of the literature together. Both teacher professional development and learning design are complex endeavours. Video analysis has been used to address very different problem sets, in very different ways, in each of these endeavours and we were keenly aware of the need to develop a stronger joint understanding of previous work. That work is reported in this section of the paper.

Video analysis literature illustrates a large variety of purposes for using video in teacher learning, from lesson analysis (Santagata, 2014) and scaffolding teachers' professional development (Brophy, 2004; Sherin, 2004) to promoting discussion between teachers (Borko, Jacobs et al., 2008) and building a learning community (Sherin, 2004; van Es, 2012). Video analysis can be defined as a systematic observation procedure on videotaped material. It identifies key elements of the behaviour, verbal and non-verbal, of videotaped subjects that are not easily seen through direct observation, and to explore the links between cause and effect in relation to the context in which the observed actions take place. It differs from "video documentary" or "video research", in that it provides for more possibilities for pedagogical research as video is used for data collection and documentation (Galliani & De Rossi, 2014). Video analysis refers to a specific use of video for research (and simultaneously, training) and is often supported by specific video analytics software, such as that originally developed for sports or motion detection. To understand the meaning of video analysis, it is necessary to foreground the concept of "analysis" as a process of focusing, individuation, isolation and recognition of

video information. By distancing the observed from the observer, video information enables the activation of interpretative and reflexive processes on specific behaviours (Tochon, 2008) and the effects on their contexts.

In this sense, through being able to provide observational data on action and the feedback related to it, video analysis affords an opportunity to help teachers think about their teaching practices and to promote professional development. Early use of video analysis is found in the area of *microteaching*, a technique that dates back to the 1960s and '70s in work by Allen and Eve (1968) at Stanford University and Brown (1975). This pioneering work was adapted to multiple applications of video analysis, such as case studies (Calvani, Bonaiuti et al., 2011), video clubs (Sherin & van Es 2009; van Es, Tunney et al., 2014) and lesson studies (Bartolini Bussi & Raploud, 2018). In all cases, video analysis is used both for research and training, identified as a tool to understand, promote and support teacher change (Guskey, 1986; Richardson & Placier, 2002) and both pre-service and in-service teacher professionalism. However, it is useful for conceptual purposes to distinguish between video analysis for research, aimed primarily to increase knowledge about teaching practices, and video analysis as a training tool, where it is used as an intervention to promote teacher change.

3.1 *Video analysis and educational research*

Educational research has always sought to focus on what happens inside the classroom, on teaching practices. In this regard, the means of research are, and have been, indirect – from a questionnaire on the description of classroom practices, through the study of teachers' beliefs and their correlations with practice, to the thinking of teachers (Shavelson & Stern, 1981; Tochon, 1993) toward the study of cognitive models of teacher planning and decision-making.

Indeed, researchers have always been fascinated by the possibility of gaining direct access to teachers' classroom practice, of opening the classroom door and observing directly what is happening inside. Practices not only include gestures, postures, verbal behaviour, but also aims, strategies, values (Beillerot, 1998; Jeannin, 2018). Direct observation has the potential to be the right research tool to open the so-called "black box" that Black and Wiliam (1998) have studied since the 1990s. The observation of teaching practices through video tries to answer this scientific challenge using different observational methodologies informed by the most important educational research paradigms. On one hand, there are classroom studies about teacher behaviours as process variables, either separated or in connection with students' learning products. This research perspective is taken in the recent TIMMS Video Study on teaching practices in mathematics and science (2003 & 2006 in Roth et al., 2006). These methods fit more closely with a quantitative-experimental paradigm, where the observer stands outside the studied context with no direct exchange with the observed teacher and focuses on specific behaviour indicators, which are collected through structured tools such as checklists, rating scales and coding schemes. This observational methodology allows the relationships between fundamental variables to be identified and compared. On the other hand, there are phenomenological-qualitative matrix studies, more related to the idea of situated environment (Rogalski, 2006; Grangeat & Gray, 2008) and an empathic understanding of what happens in a context according to an ecological model (Brofenbrenner, 1979). In this case, the tools for gathering information are narrative and open. The distance between observer and observed

is restricted but the observer is able to coach the teacher observed.

Video analysis as a research tool has developed in many directions, in the theoretical framework of different paradigms, including mixed models, characterized by the use of triangulating tools, both qualitative and quantitative. Jeannin (2018) identifies four main research directions. The first one characterizes video analysis as a research tool with systematic observations, even on large samples. The researcher guides the construction of initial hypotheses, progressively defining the constructs and behavioural categories to be observed in the video sequences. The aim is to describe and compare multiple and different situations to identify regularities and correlations in video-analyzed teaching practices. The most emblematic example to date is that of TIMMS Video Science (Roth, Druker et al., 2006).

A second research direction is that of qualitative researchers who aim to describe and understand, through video analysis, specific didactic situations. The case study is the typical design, supported by pre- and post-video analysis interviews and questionnaires to the teachers-actors. The goal is to understand in depth what happens in classrooms by crossing different kind of descriptive data with video analysis: narrative and global illustration of the event; categorical analysis (Schubauer, Leutenegger et al., 2007; Sensevy, 2007; Sensevy, Mercier et al., 2007; Marlot, 2008).

A third research direction concerns the use of video analysis informed by grounded theory (Engle, Conant et al. 2007). From this perspective, "data" flows gradually as researchers repeatedly observe the video-taped events, identify significant passages and transcribe meanings to distinguish concepts and constructs and codify actions and situations.

The last research direction identified by Jeannin (2018) is based on collaborative strategies between researchers and observed. In this case the methodological reference is ethnographic research: the video becomes the tool to reconstruct, together with the actor, the context and meanings. The researcher accesses the meanings of videos thanks to what the actor reveals (Christ, Arya et al. 2012).

In such different approaches, the observational procedures and instruments connected to them will also be different. If the collection of field notes is the basic observational tool the first time, then we will have, on one hand, more quantitative approaches where hypotheses and theoretical constructs guide the coding of the narrative data into indicators (and appropriate observation grids and coding schemes), and, on the other hand, more qualitative approaches where the field notes retain their complexity and work more on an intersubjective comparison to interpret the narrative data.

As already mentioned, some researchers combine these methodological approaches, aiming at a deep analysis and interpretation of the video and two main phases within video analysis emerge. Analysis means knowing how to see and notice the detail and to isolate and define it. Interpretation of the particular detail in the video, based on theoretical and/or experiential references, gives it meaning. These two phases form the basis for a video analysis oriented to teachers' professional development and, when applied to pre-service and in-service teacher training, they highlight the analysis of teaching practice as a fundamental element for teacher change.

3.2 *Video analysis and teacher's professional development*

Teacher change studies on how and why teachers promote change or resist it and continue to adopt ineffective teaching methods have been well developed over the last 20 years (Vannini, 2012). The main question concerns what kind of teacher training is most effective, in order to change teachers' beliefs and practices toward teaching practices oriented to students' success. There are many factors that contribute to the stability of teacher beliefs (Girardet, 2018), both in pre-service and in-service teachers, which often do not change with training or when exposed to innovative classroom practice. Where there are strong pre-existing beliefs, a lack of self-efficacy and difficult school contexts, teachers in training tend to re-establish cognitive balance by returning to previous beliefs, even when these are pedagogically inadequate (Kagan, 1992).

However, there are also many studies that have highlighted the most facilitating factors for change, which is viewed as a long and dynamic process during which theory and practice, under certain conditions, meet and mutually influence each other in order to build teacher beliefs and innovative teaching habits (Nettle, 1998). The relationship between beliefs and practices is very complex and only by considering them interdependent (Richardson, 1996; Vannini, 2012; Buehl & Beck, 2015; Girardet, 2018) is it possible to imagine effective professional development interventions. In a review of studies about factors influencing in-service and pre-service teachers' change in classroom management, Girardet (2018) found reflection on prior beliefs, studying alternative practices, learning by doing, reflection on practice and a collaborative learning environment to be the most influential.

As can be seen, the focus on own and others' practices and reflection, individual and collective, and beliefs and practices are the key elements for change. In this sense, video analysis – as well as microteaching since its origins – presents an interesting opportunity given its potential for teacher professional development. It turns from a research tool into an effective training tool. Richardson and Kile (1999) even argue that when video analysis is used to promote teacher change, the separation between research and training no longer exists.

Video analysis offers an opportunity to reflect on practice and implement training during which the teacher acts, observes, receives feedback, reflects, plans, and acts again, promoting what Castoldi, Damiano et al. (2007) refers to as reflection-in-action. Videos become a valuable tool to support the teacher's conceptualization of action, using diverse methodological approaches. Through video analysis procedures, teachers can be helped to exercise analytical thinking about their own and others' practice. The focus on detail and performing action in the classroom allows the teacher "in training" to notice the action, re-think it, assign it meaning and then gradually distance themselves from and see it critically. More specifically, the habit of observing what happens inside the classroom is a very important tool for helping a teacher in training to start from practice and re-think and re-design it (Danielson, 2007). Observation focuses on empirical data, the "actions and behaviours" within real life contexts. Teachers can then compare their beliefs with such empirical data and use them to structure and re-structure new beliefs. The data emerging from a valid systematic observation procedure makes it possible for the observed subject to step back from the action performed and view it critically (Lovece & Vannini, 2018).

Internationally, many prominent teacher training associations are moving towards this type of training, for example the OECD (2018) and UNESCO (2018) in Europe, the Bill and Melinda Gates Foundation (2013) in the United States, uni-

versities in Canada (Karsenti & Collin 2011). They align with a substantial body of research that shows the positive impact of studying real-life classroom situations and the exercise of teachers' analytic ability (Sherin & van Es, 2009) to decode and interpret them and reflect and plan in new ways (Beck, King et al., 2002; Bruning, Siwatu et al., 2008; Choi & Lee, 2009; Rich & Hannafin, 2009; Cevik & Andre, 2013) towards the development of a professional vision. There has also been a substantial amount of research in the different ways of using video analysis by English-speaking (Guernsey & Ochshorn, 2011) and French-speaking researchers (Laveault, 2009; Meyer, 2012), and U.S. teaching associations (cf. TNTP, 2018, New America, 2018; Teachstone, 2018), which have found support for reflexivity tools (Bonaiuti, Santagata et al. 2017; Ferretti, Michael-Chrysanthou & Vannini, 2018) lesson study (Bartolini Bussi and Raploud 2018) and video clubs (Sherin & Han, 2004, Sherin, 2007). In all these cases, video becomes an effective tool for decentralizing oneself, removing action from the here and now, slowing the emotional burden and triggering systematic processes of thoughtful thinking.

Accordingly, the teacher may follow these steps:

- exercising analytical thinking on video sequences;
- noticing and describing slowly with words (conceptualization);
- looking for cause-effect links;
- identifying possible alternatives compared to those observed.

This process takes in moments of individual reflection and collaborative discussion with other teachers. Obviously, the effectiveness of these directions in teacher training is linked to the consistent and intentional use of tools to support reflection. In this regard, video self-analysis, in which the presence of a critical friend is essential (Richardson & Fallona, 2001), can be distinguished from video hetero-analysis, which sees individual and group reflection moments integrated with discussion with an expert.

3.3 *Innovations in video analysis for pre-service and in-service teacher's professional learning*

Recent innovations in video analysis technologies, including video annotation and video analytics software, are noted in studies conducted by Calandra, Brantley-Dias et al. (2007), Chatti, Marinov et al. (2016), Colasante (2011), Goeze, Zottmann et al. (2014), Khurana and Chandak (2013), Mirriahi, Jovanovic et al. (2018), Mu (2010), Pardo, Mirriahi et al. (2015) and Rich and Hannafin (2009).

Video annotation tools are used to facilitate a user's interaction with video content. They provide the means by which users can create and respond to comments posted onto the video time line or post as chat within an adjacent dialogue box. Originally used in qualitative research outside education, video annotation has expanded into education over the last decade (see Pardo, Mirriahi et al., 2015). These tools enable teachers to 'review, analyse, and synthesize captured examples of their own teaching in authentic classroom contexts' (Rich & Hannafin, 2009, p.53). With time-stamped annotation features, annotation software enables educators to make comments and reflections which can be shared with peers and educators (Pardo, & Mirriahi et al., 2015). Examples of annotations tools include Coursemapper (Chatti, Marinov et al. 2016), VideoAnnEx (Lin, Tseng et al., 2003), the Video Interaction for Teaching and Learning (Preston, Ginsburg et al., 2005,

Lee, Ginsburg et al., 2009), MuLVAT (Theodosiou, Kounoudes et al. 2009), WaC-Tool (Motti, Faga Jr et al. 2009), the Media Annotation Tool (Colasante, 2011), the Collaborative Annotation Tool (Harvard University, n.d.), and the Collaborative Lecture Annotation tool (CLAS) (Risko et al., 2013).

Video annotation tools have been perceived positively by pre-service teachers (Colasante, 2011; Colasante & Douglas, 2016) and can enhance teacher reflection by providing a platform and structure for analysis (Rich & Hannafin, 2009). Recent research has started to document the positive effects of video annotation on academic performance. Kleftodimos and Evangelidis (2016) examined learner sequences of activities within video (i.e., viewing patterns) and found that these were related to exam performance. More advanced video analytics have also been carried out specifically with video annotation tools. Mirriahi, Liaqat et al. (2016) employed 12 variables from clickstream data captured in video annotation software, and analysed these with transition graphs. Using cluster analysis, they identified four profiles of students that were related to academic performance. Chatti, Marinov et al. (2016) presented a new video annotation tool called Coursemapper, which boasts a unique feature whereby heatmaps are created from learner traces to reflect most viewed segments of video, and annotation maps highlight segments that are frequently annotated. Students found this feature useful in terms of helping them quickly identify popular videos thereby reducing cognitive load. In all, these studies show the possibility of employing educational data mining (EDM) approaches to video analytics in ways that inform learning.

However, at least one study has found that there is in fact no difference between having to annotate a video and simply watching it, regarding the outcome of confidence (Fadde & Sullivan, 2013). This suggests that more research needs to be done to inform a better understanding of video pedagogy in pre-service teacher education (Blomberg, Renkl et al., 2013; Chittleborough, Cripps Clark et al., 2015), and how video annotation pedagogy can facilitate better learning outcomes. Research on video annotation tools and users' perceptions of their benefits and limitations are evident, however the actual annotations themselves have, to date, rarely been examined. This is a significant gap, as video annotations are potentially a rich source of information about how students are constructing knowledge about what they are learning.

This research gap is more sharply defined when considering the lack of use of video annotation tools in pre-service mathematics teacher education courses or teacher development programs. In one Australian context (University of South Australia) and, emanating from work conducted by Risko, Foulsham et al. (2013) regarding Collaborative Lecture Annotation System (CLAS), is the deployment of Online Video Annotation for Learning (OVAL) software. OVAL is currently being trialled to explore the affordances – a term used by Arenas (2015) to denote actionable possibilities – of video annotation coupled with learning analytics to study pre-service teacher's modelling of practice in finer-grained detail. OVAL affords course coordinators facility to import OVAL as an external tool into their course allocating viewing privileges to specific groups who are then enabled to collaboratively view, annotate and post responses about the video recording. Leonard and Westwell (in press) have demonstrated that providing structures for teachers to work collaboratively to engage with real problems of practice can promote lasting reform. This pilot aims to analyse pre-service teachers' enacted knowledge, meaning-making and co-construction, and/or specific traits or characteristics of teacher's teaching through role modelling and peer presentation. For discussion of models of analysis akin to annotation practice see also Colvin, Rogers

et al. (2016), Cotrell and Doty (1971), Kourieos (2016), Savas (2012), Gardner and Gardner (1969) and (Young 1968).

Video analytics, which sees video interaction data analysed at scale to understand and improve the effectiveness of video-based pedagogies, is a very recent additional development in video analysis. While research in this area is still in its infancy (Giannakos, Sampson et al. 2016) those devoted to this field contend that an applied use of video analytics in educational research may provide greater understanding about learners' engagement and outputs. Movement is this space is evident from the inaugural Workshop of Smart Environments and Analytics on Video-Based Learning was held as part of the 6th International Learning Analytics Knowledge Conference (2016) to connect research into video-based learning with that on smart environments and analytics to create synergies between these fields. As noted by Giannakos, Sampson et al. (2016, p. 502) 'as a step toward improving learners' experience and engagement with video-based learning systems; students' activity might be converted via analytics into useful information and benefit smart environments efficiency and ultimately learners experience and performance'.

While machine learning (ML) has not sufficiently been able to seamlessly extract and thematically analyse audio tracks that accompany video data, advances in this field have surfaced recently, most notably from Tech-companies; Google, Microsoft (Cognitive Sciences) and Mangold, where software has been designed to read, record and interpret in real time, gestures and facial features sentiment, language and vocabulary, as well as track motion and movement. However, to more fully accomplish the task of extracting and thematically analysing audio tracks that accompany video, machine learning requires more sophisticated, responsive software that automatically assimilates, accommodates and synthesises the complexities and subtleties of human's interactions and language. ML tools capable of recording, reading, and analysing teacher/learner engagement, enactment and feedback may provide significant purchase in the creation of highly responsive learning designs and interventions particularly in mathematics education, where students' disengagement and under-achievement have been characteristically problematic across Westernised schooling systems.

4. New directions in research

In a world increasingly shaped by smart devices and social media, meanings and values transmitted through multi-media modalities, such as video, cannot but reimagine traditional approaches to teaching and learning especially those that continue to position the teacher at the centre and controller of knowledge (Moreno & Mayer, 1999; Siemens, 2005; Anders, 2015; Bingham, Reid et al., 2016). Arguably the role that video and virtualised messaging now plays in the co-construction of knowledge is worthy of critical attention by educators and this point is particularly curt in consideration contemporary teacher-learner contexts regarding in pre-service and in-service teacher education programs, and the means from which to improve course delivery and practice through digitally enhanced learning design (Elliot, Sweeney et al. 2009; Ellis & Goodyear, 2010; Lockyer, Heathcote et al., 2013).

The FAMT&L project (Ferretti, Michael-Chrysanthou & Vannini, 2018) is one powerful example of a recent international initiative that situates video analysis in teacher's professional learning. And, emanating from Australia, studies on video

annotation and learning analytics technology conducted by Gašević, Dawson et al. (2015), Pardo, Mirriahi et al. (2015), Risko, Foulsham et al. (2013) have led to the development of OVAL for use in pre-service teacher education. This additional suite of video analysis technology is thought to provide strong potential to greatly enhance pre-service teachers' meaning-making and professional practice when constructively engineered into course learning design.

Gašević, Dawson et al. (2015) and Lockyer and Dawson (2011) contend that the affordances that video analysis software supply to educators and researchers, as noted above, are predicated on the positioning of these technologies in purposeful learning design. By learning design, these authors point to the intentional engineering and architecture of a course or program that is underpinned by well-theorised pedagogical intent and practice. Similarly, Biggs (1996, 2012) and Elliot, Sweeney et al. (2009) outline development of well-informed constructivist learning sequences which involve leaners in exploratory, explanatory and applied learning tasks moving them from noticing, to salience, to synthesis. Learning design thus is used a term to include all intended aspects of teacher's work from planning, implementation and assessment perspectives positioning these practice architectures (Lowrie, Leonard et al., 2018) within strategies and principles deriving from constructivist and connectivist theorising.

Lockyer & Dawson's (2011) proposition is that when learning design is coupled with learning analytics, educators and researchers are provided powerful potential rapid responsive tools from which to analyse teaching and learning, thus making timely interventions to support and or nourish learners. This they contend lends food for thought when considering reforms driven by government and institutions that demand quality, replicable and scalable teaching and learning approaches evaluated through data sources such as learning analytics. The challenge they present is that a learning design approach need be founded on its case-based merit. How that case becomes translatable into scalable practice whilst maintaining its socio-cultural, structural and pedagogical integrity is another key question posed.

4.1 *Improving mathematics teaching*

Identified through our joint exploration of the literature, the main aims of our research collaboration are to explore how:

- Video analysis technologies serve to support pre-service teachers' co-constructions of mathematics education from knowledge and practice standpoints.
- Pre-service teachers better understand how to design and implement effective approaches to teaching and learning mathematics.

From our joint perspective, educational inquiry that utilises video analysis technologies to notice, reflect on, inform and reflexively influence educator's practice, conjoins with similar studies conducted elsewhere (Hiebert, Stigler et al., 2005; Tripp & Rich, 2012; Coffey, 2014; Ludecke, 2014; Santagata, 2014; van Es, Tunney et al., 2014; Gašević, Mirriahi & Dawson cited in Gašević, Dawson et al., 2015; Darling-Hammond, 2016; Mitchell & Reid, 2016; Lowrie, Leonard et al. 2018). The additional elements of surprise we bring to this study are the purposeful inclusions of video annotation and video analytic tools, which are housed within a course learning design (Elliot, Sweeney et al. 2009; Ellis & Goodyear, 2010; Crisp, 2011; Lockyer, Heathcote et al., 2013) and/or practice architecture (Lowrie,

Leonard et al. 2018) that seeks to optimise their affordances (Dawson, Bakharia et al. 2010; Arenas, 2015; Cheng & Leong, 2017).

While research on video analysis is abundant, research on the use of video annotation tools combined with video analytics has rarely been examined. This is a significant gap, as data drawn from these additional tools are potentially rich in information about how students co-construct, engage with, and enact professional knowledge. This research gap is more sharply defined when considering the lack of use of video annotation and video analytics in pre-service mathematics teacher education courses. Thus, the term video analysis technologies in this research encumbers the above additions as a suite of tools.

Using video analysis technologies as tools for teacher learning, the researchers are guided by questions that can be summarised as follows (Santagata, 2014):

- What is the teacher learning purpose of using video?
- What types of video will work for that purpose?
- What viewing modality will best serve that purpose?
- How can we assess that we have achieved our purpose?

Approaching these questions suggests a multi-dimensional research framework:

a) Measure impact on students' developing pedagogical content knowledge including their developing sophistication in understanding curriculum frameworks, effective teaching approaches and they application of research informed strategies for teaching mathematics effectively.
b) Measure pre-service teacher' confidence and proficiency towards teaching mathematics.
c) Ascertain translation into practicum based on prospective assessment (viva and presentation assessments) and retrospective collaborative assessment post practicum.
d) Gather data from a range of sources including collaborative peer assessment of weekly group presentations, formative assessment from OVAL Annotations and video analytics, and summative assessment techniques (teacher and peer assessed and viva) and other related system-based learning analytics to gauge students' self-reported performances as well as their graded performances.

4.2 *Improving learning design*

As mentioned previously above the term learning design is suggestive of logics drawn from actions and possibilities relating to the engineering of learning within an architecture of practice (Kemmis, 2014; Lowrie, Leonard et al., 2018). We are also guided in our use of this term by Elliot et all's. (2009) study which grounds learning design deeply within constructivist pedagogy that has an intended learning focus on learners raising cognition through practice-based inquiry also referred to in the context of their study as problem-based learning or authentic learning (*ibidem*). This approach dovetails cleanly with Bigg's (2012) notion of constructive alignment whereby learners move from states of awareness through to mastery and application of assessable knowledge. Essentially this design affords the learner to notice, explore (question), explain (collaborate and share) and apply their knowledge through enactment of assessment (formative and summative).

Pre-service teachers are also required to work in learning teams and this social learning aspect of the learning design is informed from King and Sen (2013) and Michaelsen and Sweet (2008).

Procedural elements of this learning design are as follows:

1. Teams of three students present a total of six presentations, which require them to theorise, explore, explain and model teaching and learning of mathematics. Pre-service teachers are organised into table groups comprising two teams of three students. At each table, one team of three presents to the other team of three (observers), who peer-review the performance. Each presentation is video recorded from dual vantage points.
2. Prior to their presentation, each team has access to a scaffold that outlines the key conceptual and pedagogical points to be covered in their presentation, including a selection of relevant literature for review. During the presentation, observers also provide constructive verbal feedback and produce a marked-up peer review sheet using qualifiers: "sound", "good", "very good" or "excellent". Post presentation, the tutor formally assesses the team's PowerPoint presentation. On request, groups may view the raw footage and or thumbnails which in can be provided on a portable share drive for review and or editing.
3. The research team then edits the raw clips into smaller 3-5-minute snapshots in which questions and comments are posed in OVAL for response. During the final two weeks of the course, groups access their video clips via OVAL software from the course site in Moodle (the university's learning management system), from which they can collaboratively annotate and analyse their clips. Subsequently, annotations as text, and analytics as engagement, are then mined for analysis. In this research the video clips are used only as a mode for reflection and comment made available to the individual, team and table group. In future research a higher level of ethical consent will be applied for to dig deeper into these video data.

5. Conclusion: Innovating methodology directions

Emerging from this engagement with the literature we see potential for innovations in research methods such as analysing large volumes of qualitative text sourced from pre-service teachers written responses (video annotations, narratives and assessment artefacts) using both innovative structured tools and common known tools, Coh-metrix, and Language Inquiry & Word Count (LIWC) for example, which provide insight into linguistic structure and other linguistic features including sentiment (emotion, psychological dispositions) as revealed in writing (Graesser et al., 2011; Bell et al., 2012). Therefore, the innovation methodology directions will draw on natural language processing (NLP) tools and/or methods to analyse the video annotation data for insight into students' construction and co-creation of meaning. Finally, the resultant video analytics – that is, the trace data generated from users' interactions with the video – could be interrogated to explore how student teachers used the video annotation tool for reflection and learning. Akin to Gašević & Dawson's (2015) study, both user activity and quality of the learning products will inform the evaluation of this learning analytics project. It is also highly likely that further collaborations with colleagues either based at the University's Teaching Innovation Unit, or elsewhere, may generate a suitable tool(s) that reads and interprets proximities of coherence and cognition derived

from pre-service teachers' annotated video responses and assessment artefacts. This is especially the case with cross-over and close collaboration already forged between the University of South Australia and the University of Bologna and their cross-border FAMT&L project which relied heavily of video data and thematic analyses techniques.

The affordances of using video analysis technologies in learning design appear highly attractive. Pre-service teachers are imagined connecting professional reading, noting, discussion and presentation in seamless iterative episodes of learning. Collaborative viewing and annotation of their group presentation via video technologies provide a powerful new layer from which to construct and co-create meaning about their teaching and learning of mathematics education. The applied use of video analytics seeks to extrapolate from learning design rich seams data that can analysed using ML tools such as coh-metrix, LIWC or other natural language processing (NLP) tools.

The study hopes to provide a well theorised and evidence-based case study which may in the first instance translate to the production of more capable mathematics teachers and second, trigger capacity for more scalable projects to ensue suited to in-service teacher education programs. The need for improvement in mathematics teaching in Australia, if not elsewhere, has been noted. As with the FAMT&L project, the use of video technology as a multi-media teaching and learning tool provides a solid contribution to educator's supply of contemporary professional resources.

However, the logistics of using video technologies should not be underestimated. Use of video technology is labour intensive. Significant time and effort are required to wade through and edit video and careful consideration must be given to the secure warehousing and management of video data. With advancement in video hardware and software and in this case, utilisation of a smart learning environment, these concerns are somewhat mitigated.

While we as university teachers are within our mandate to seek improvements in teaching and learning, we must always consider the ethical impact that our studies have on its participants. This research study has a clear mandate to work with pre-service teachers and to actively include them in the design of the study. We have learned that not all students are comfortable about the use of video for reflection and analysis purposes, and these students are able to opt out of the project without repercussion. With that in mind, we have promoted the idea that the work of educators is always in the public's view and always public in the way educators communicate and justify their teaching. Educators are always professionally and passionately defending their teaching through their knowledge base and through their practice and this this project aligns with developing professional capacity, efficacy and resilience. However, the greatest benefit we have promoted in this research venture is the benefit gained from the development of professional knowledge, especially regarding more effective teaching and learning of mathematics.

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