Digital Makeover: What do pre-service teachers learn from microteaching primary science and how does an online video analysis tool enhance learning?

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Abstract
This paper reports on pre-service teachers' experiences of using the web-based video analysis tool VideoAnt during microteaching seminars in primary science. Opportunities for pre-service teachers to observe and teach high quality primary science lessons during placement may be restricted by the focus on Numeracy and Literacy and recently reported decrease in the profile of science within the primary curriculum. This in turn will compromise the confidence and competence of future teachers with respect to teaching science. Within initial teacher education Microteaching continues to be used widely as a means of introducing the practice of teaching in a gradual and controlled manner. Data obtained from questionnaires and focus group interviews of 93 undergraduate students suggests that the online video analysis tool VideoAnt adds significant value to the learning resulting from each of the three features of microteaching; shortened lessons, video analysis and feedback. The majority of pre-service teachers enjoyed using the tool and reported that the experience had increased their levels of confidence in teaching primary science and that as a result they would now be better equipped to learn during the course of school placement. The findings may help address the challenge of achieving greater integration between the college-based and school-centred components of ITE programmes, and enhance pre-service teachers' experience of teaching in curricular areas such as primary science where the opportunity for practice during placement may be limited.

Keywords
Microteaching; video; reflection; practice; assessment; on-line.

Introduction

Microteaching has been used widely within initial teacher education programmes across the world since it was first devised in the 1960's by Dwight Allen (1967) at Stamford University. As the name suggests, it was designed to provide pre-service teachers with the opportunity to look very closely at a particular aspect of their teaching within the controlled environment of an initial teacher education institution. Over time, as its popularity grew, the key features which characterise microteaching came to be:

- shortened teaching episodes
- the use of video playback
- feedback from tutor and or peers

Whilst originally conceived as a means of focussing on the more technical aspects of classroom teaching such as presentation skills, its potential to develop pre-service teachers' reflective and critical thinking skills has been widely reported (Diana, 2013; Bell, 2007; I'Anson, Rodrigues and Wilson, 2003).

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Despite improvements in the quality and quantity of primary science in the UK recent reports call for more continuing professional development for teachers, and for science to be given a higher priority within the school curriculum (The Welcome Trust, 2017; Ofsted, 2016; Confederation of British Industry, 2015). Within its 'recommendations for reviving primary science' The Welcome Trust (2014) include a commitment to high-quality initial teacher training. Bakir (2014) reports how microteaching teaching proved to be effective in developing pre-service teachers' teaching skills and their confidence in primary science.

Advances in video technology have changed what pre-service teachers learn from microteaching and have also shaped theories on how they learn (Siry and Martin, 2014). This study explores pre-service teachers' experience of microteaching and how developments in digital technology may be used to add value to microteaching and help contribute to an effective pedagogy for initial teacher education. As Academic Collaborators for the Primary Science Teaching Trust our research activity includes devising and evaluating effective pedagogies for science teacher education.

A pedagogy for initial teacher education

As the use of school-centred initial teacher education within the UK shows no sign of declining it is vitally important that university and college-based initial teacher education programmes focus on ensuring that pre-service teachers possess the skills and dispositions required to learn within the complex and challenging context of a school. There have been calls for greater research into what constitutes effective practice in ITE in the UK (Burn & Mutton, 2015; Tatto & Furlong, 2015) and beyond (Darling-Hammond, 2010; Menter, 2016). Hiebert et al. (2007) propose a greater focus on activities where pre-service teachers develop key competences through analysing teaching. The need to examine the provision within ITE programmes in the UK becomes more acute in light of Hobson and Malderez's (2013) data which identifies problems at each of the levels of the school-based mentoring process. Kenny (2010:1268) cautions that when it comes to the amount of time which pre-service teachers spend in school, 'more is not necessarily better'. Philpott (2014) proposes that the discussion on initial teacher education should focus on the 'how' as opposed to the 'where'. Carter's (2015:21) report on initial teacher education in the UK calls for careful consideration to how trainees' learning experiences are structured so as to avoid privileging 'theory' or 'practice' in an environment, 'where trainees have access to the practical wisdom of experts and can engage in a process of enquiry, in an environment where they are able to trial techniques and strategies and evaluate the outcomes'. Osborne and Dillon's (2008) critical reflections on science education across Europe observe a recent shift towards practice in the UK and call for a more even balance with theory. Orchard and Winch (2015) contend that the environment of a university is more conducive to the kind of theoretical learning needed by new teachers, which often involves sustained discussion and the sharing of ideas away from the immediate pressures of the workplace. So how might microteaching be developed to ensure that the theory-rich climate and the supportive setting of an ITE institution best enables student teachers to begin to learn about teaching through teaching?

Microteaching and initial teacher education

The key features identified in Allen's (1967) description of microteaching - reduced lesson duration, use of video, and the provision of feedback- have featured in the design and evaluation of almost all studies of micro-teaching to date (Morrison, 2010). Other studies have conceptualised it as, 'the opportunity to practice in an instructional setting in which the normal complexities are limited' (Benton-Kupper, 2001:830) or 'a scaled-down teaching encounter' (Cruickshank & Metcalf, 1993:87).

On-campus activities such as microteaching have proven particularly effective when it has not been possible to provide school placements deemed appropriate to the particular aims and needs of an ITE programme. Dawson, Pringle and Adams, (2003) made use of microteaching when it was difficult to get suitable school placements where their student teachers could develop their skills in using ICT within teaching. Metcalf, Hammer and Kalich (1996) reported how a group of pre-service teachers who had only experienced microteaching activities on-campus, out-performed a group who had only experienced school placement. They thus recommended microteaching as a means to develop pre-service teachers' interactional and reflective skills in the controlled environment of a university.

Primary Science initial teacher education in Northern Ireland

In Northern Ireland the need for college-based ITE practices which encourage and support student teachers through their early attempts to teach primary science are urgently required. Recent reports highlight a marked decline in the quality and quantity of science being taught in our primary schools since curricular reform in 2007. The recent Education and Training Inspectorate's report (ETI, 2015) found that the provision for science and technology was under-developed in 54% of the schools surveyed, and that 27% of primary school teachers did not feel confident in teaching primary science and technology. These findings are consistent with Johnson's (2013) claim that the proportion of time allocated to teaching primary science has reduced in recent years. This decline in the profile of science within the primary school limits the opportunities for student teachers to observe, let alone teach primary science during school placement. Research by Lowry (2017) within one ITE institution found that approximately two thirds of final year undergraduate pre-service teachers had taught only six lessons or less during the four years of their B.Ed programme. This in turn is likely to result in graduate teachers who are less competent and confident in teaching science and is likely to seriously compromise the future quantity and quality of primary science in our schools. A similar 'Catch-22' scenario relating to science education in Australia has been described by Kenny (2010), where in-service teachers lacking in confidence are less likely to model best practice for observing pre-service teachers let alone encourage or support them to teach science during their placements. We feel that it is vitally important that initial teacher education institutions strive to break this potentially reductive cycle by providing on-campus learning activities which encourage and support pre-service teachers through their early attempts at teaching primary science.

Methodology

Research Design

The aim of the research was to access and explore pre-service teachers' views and experiences through two cycles of microteaching primary science, where the second cycle involved the use of an online video analysis tool. Therefore an interpretivist paradigm was adopted in order to 'best understand the subjective world of human experience' (Cohen, Manion and Morrison, 2011:17). The study is best described as a case study of the how and why of microteaching (Yin, 2012), where the case was an investigation of one cohort of undergraduate student teachers within one ITE institution. The nature, structure and sequence of the microteaching tasks were aligned to the overall module learning intentions to develop the pre-service teachers' confidence and practice in primary science in preparation for school placement. They are likely to be very similar to the content of most other pre-service science education course which should potentially enhance the transferability and validity of the findings to other ITE programmes.

The research was guided by the questions:

- How does microteaching support learning?
- Does VideoAnt enhance the key features of microteaching?
- Did this experience of microteaching influence the student teachers' future teaching intentions?

Participants and Ethical Considerations

As the microteaching activities were core elements within this undergraduate module they were carried out by the entire cohort of 98 students. Consent to participate in the data collection activities was obtained from all participants, but due to student absences data relating to 93 students was obtained. The research was carried out within the ethical protocols of the University College and ensured that:

- Students were free to opt out at any stage during the data collection activities.
- Student identity remained anonymous.
- The research activity had no bearing on the module assessment rubric.
- Permission was obtained from the individuals to include their photograph in Figure 1.

Data Collection and Analysis

A questionnaire containing closed and open questions was administered after the completion of each of the two cycles of microteaching. All participants were then invited to take part in a focus group interview conducted by one of the researchers with the second researcher present in the role of observer. Four groups of five students consented to participate. The interview schedule included similar questions to the questionnaires and allowed the interviewer to explore emergent themes and provided a 'chain of evidence' (Yin, 2009: 41) to enhance the reliability of the findings. The questionnaire provided descriptive statistics for the closed questions and allowed for a thematic analysis of the open-ended questions. The focus group transcriptions were independently analysed by each researcher. The themes identified by both researchers for each question were compared and any resulting divergence in opinion was resolved by discussion.

Microteaching Activities

Microteaching 1

Working in groups of three, the pre-service teachers planned, taught and evaluated a short 15 minute science lesson. One member of the group taught the introduction (5 minutes) with the other two members teaching the pupil activity and the plenary (each 5 minutes long.) Each group was provided with a digital video recording of the lesson and was required to watch the recording, discuss it and identify strengths and areas for development in both their own and their peers' practice. This took place within a timetabled evaluation seminar during which each student completed an evaluation feedback form.

Microteaching 2

Working in the same groups the pre-service teachers were required to plan a follow-up lesson as for microteaching 1. This time the evaluation task involved the use of the on-line analysis tool VideoAnt.

VideoAnt

This is an online synchronizing web-based application which allowed each student to add time marked annotations to their video. Each student was required to identify strengths and areas for development in their own teaching and to add comments or questions about their peers' teaching. The pre-service teachers were also required to use the 'respond' facility to reply to any of their peer's annotations. A typical VideoAnt is shown in Figure 1. below.

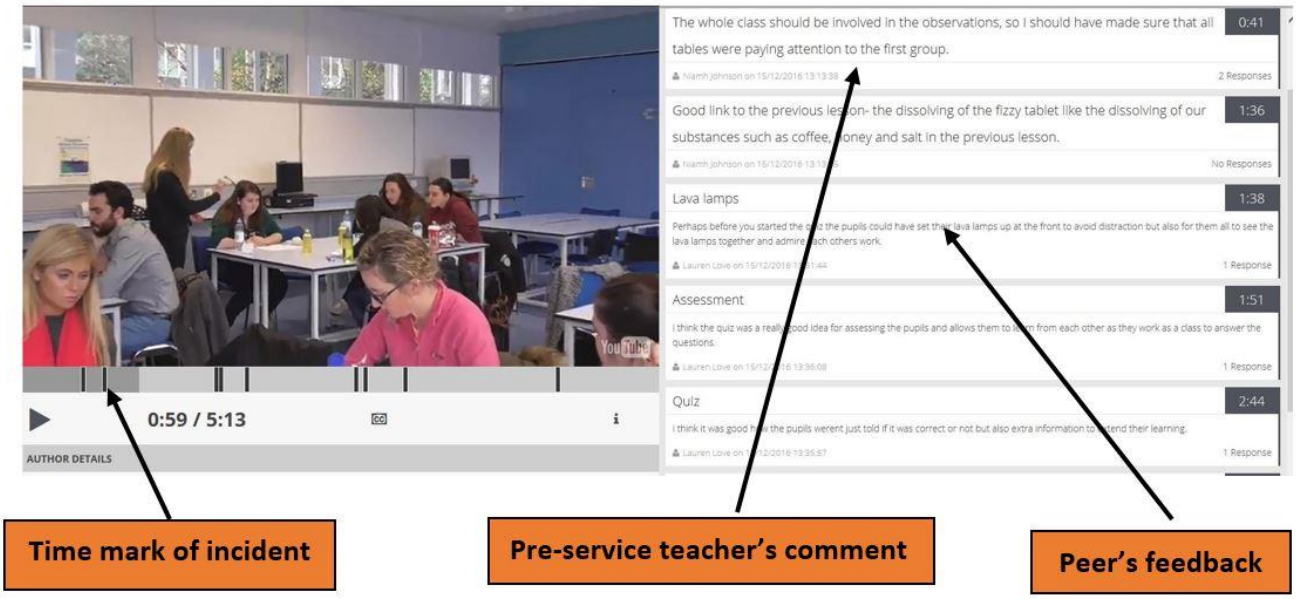

Figure 1. Screenshot of a typical VideoAnt.

Findings

Does microteaching support learning?

Data from the questionnaire found that 85% of the pre-service teachers felt that the microteaching experience was useful, 10% were 'unsure', and 5% felt that it was not useful. The majority (86%) of pre-service teachers felt that observing their peers' teaching was equally as useful as actually teaching, with the remainder equally split between the two activities.

Impact on Planning

The opportunity to plan with peers was valued by all participants. This was reported to provide access to a wider range of ideas and prior experiences and enhanced the collective subject knowledge of the group. The peer discussion arising from co-planning was frequently cited as being helpful. Quotations from the focus group interviews are presented below.

> When I am planning a lesson my ideas get trapped in my head and I follow on planning it out. But in the group you had to explain it and were thinking it through and somebody would say ''that won't work'' and you then see it needs changed
>
> (Student 6).

Some pre-service teachers valued experiencing different approaches to planning and the opportunity to talk to their peers about how they go about it. Working in a team also provided moral support:

> It was so less daunting than being on your own but you still made your contribution and wanted it to be good for everyone. When others would say my plan was good I got more confidence and thought that my ideas were as good as anyone else
>
> (Student 9).

Impact on Teaching

Almost all (95%) of pre-service teachers valued the opportunity to actually teach a science lesson. Acknowledging their limited experience in the classroom, many stated that teaching their peers allowed them to focus more on their presentation skills without the many other challenges presented by the complex environment of the classroom. However not being able to interact directly with pupils was considered by 3% of the pre-service teachers to restrict the learning opportunity:

> It was a bit false asking questions when you knew they always knew the answer. I didn't have to direct the class as much with children so didn't get to practice classroom management
>
> (Student 5).

Realising how much science could be covered in a relatively brief time period was cited by a few students as an additional advantage of engaging with short lessons.

Impact on Evaluating

This was the aspect of their practice which students felt had been developed most. Watching the video was hugely beneficial as was the feedback from peers and tutors. Many pre-service teachers described the value, and in many cases, the shock of seeing themselves teaching. Though initially painful for some, it revealed physical aspects of their teaching, such as voice and body language, which they could see needed to be developed. Having a 'pupil's-eye view' of the lesson forced many to question how engaging was their presentation and required them to think about effective strategies for showing exhibits and demonstrating activities in a classroom:

> I seemed so far away from the class so it made me think that I should move about more and bring the lesson down to pupils' tables more often
>
> (Student 4).

For many this was their first experience of evaluating their practice with peers:

> During placement I am just evaluating on my own. But now it was great to have others to talk with and get their feedback
>
> (Student 5)

The video playback was considered to enrich the discussion:

> With the video we had something concrete to talk about. So much of the lesson is forgotten, but the video showed it all and was evidence about what you were saying
>
> (Student 7).

<u>Does VideoAnt enhance the key features of microteaching?</u>

Practically all of the students (98%) found using VideoAnt to be straightforward with 88% of the group stating that they enjoyed the experience. Table 1. shows the pre-service teachers' views on how VideoAnt impacted on the three key features of microteaching; teaching a short lesson, using video-playback and feedback.

Table 1. Students' views on the key features of VideoAnt.

Feature of Microteaching	Aspect of VideoAnt	Yes (%)	Not Sure (%)	No (%)
Short lesson	Choosing an exact incident was more helpful	95	3	2
Video Playback	Learn more than just watching	89	7	4
	Annotating required more thinking	92	7	1
Feedback	Reading peers' comments was useful	99	1	0
	Responding to peers' comments was useful	79	12	9

Teaching a short lesson

Although the teaching episodes were very brief the pre-service teachers valued the facility to pin-point an exact moment in the lesson and carry out a 'micro'-level analysis of their actions. During interviews several described how this close analysis made them fully realise the vast number of things which can happen during even a short lesson, and firmed up the connection between planning and teaching:

> I could see clearly I was jumping in too quickly after a question. I hadn't waited and then my clues weren't helpful. I hadn't planned what exactly I would ask or what to do if they didn't get it
>
> (Student 9).

When selecting an incident from their lesson for comment, the students described their efforts to identify the exact starting point for the time-marker and how this required repeated viewing which often showed up something which had previously gone unnoticed. Such a close analysis was considered to be well suited to shorter teaching periods and made the task of evaluation much more manageable:

> I could single out the exact thing I wanted to comment on within all the lesson, so that helped me to just focus on what I did then and if it was good
>
> (Student 8)

Video playback

There was a strong consensus that the interactive features of VideoAnt made for a better learning experience. Both the time-marking and the addition of explanatory text were identified as very helpful. They valued the opportunity to decide which part of the lesson to select for discussion, as one

student stated that he 'liked being in control of what would be analysed.' The task of adding explanatory text was considered by several students to require them to think more deeply about their teaching and challenged them to articulate their thoughts more clearly than when just talking about their teaching:

> I thought I knew what I was going to say and then when I started typing I'd realise I wasn't sure and have to think it through again
>
> (Student 7).

Feedback

The questionnaire data showed that practically everyone considered reading feedback from peers to be useful. The interviews revealed that the students found seeing affirmative responses and agreement with their own comments to be reassuring and a source of encouragement. The potentially sensitive issues of admitting to 'mistakes' or 'praising yourself' also featured in the discourse:

> I find it hard to say positives about my teaching so it was great when my peers would pick something out which they thought was good. When I said something was a weakness it was nice to hear that someone else had struggled with this too
>
> (Student 5)

However the proportion who considered 'responding' to feedback to be useful was smaller than for just 'reading' feedback. Providing feedback was also considered to a most valuable activity:

> You could see the lesson from a tutor's point of view, and have to think what can I say here?
>
> (Student 3).

Did microteaching influence future teaching intentions?

All students reported that as a result of the two cycles of microteaching, they now felt more motivated to teach science during their placement and that they were now in a position to learn more from being in school. The various themes and relative frequency of citation by the students are listed below in Table 2.

Table 2. Why pre-service teachers feel they will now learn more from placement.

Theme	**% of all responses**
More aware of strengths and weaknesses in my teaching	26
Better at evaluating my teaching	23
Increased confidence in teaching science	22
Better at teaching	18
I have more ideas for teaching science	16
More aware of how I'm coming across to pupils	11

The major themes were a greater awareness of the areas of practice which require development and an increase in confidence in teaching and evaluating.

77% of participants expressed a desire to use VideoAnt again within their B.Ed programme (18% were 'not sure' and only 5% opposed to the suggestion).

Discussion

Microteaching and science teacher education

All of the participants reported that the microteaching activities had increased their ability to plan, teach and evaluate science lessons and as a result they felt more confident about teaching primary science in the future. We feel that this is a significant outcome as a lack of confidence may result in pre-service teachers avoiding teaching science (Kenny, 2010) or adopting a more didactic teacher-centered approach which is totally at odds with current models of best practice in science education (Appleton, 2008). The benefits of microteaching go way beyond the development of technical aspects of presentation and the rehearsing of instructional activities. Microteaching provides a means by which initial teacher education programmes can respond to Roth et al's (2008) call for the temporal, physical and social space for pre-service teachers to analyse their own and their peers' teaching of science. Each of the activities (planning, teaching and evaluating) relate directly to an individual's practice and therefore are learner-centered and scaffold the challenge of learning to teach science through social interaction (Bell, 2007). We believe that the provision of a rich and authentic context for discussion and interaction with peers is central to the effectiveness of microteaching. Siry and Martin (2014) have demonstrated how pre-service teachers' use of video analysis and cogenerative dialogue can transform their science teaching and help develop their reflectivity. Van der Westhuizen (2015) claims that peer collaboration during microteaching provides opportunities to engage in pedagogical reasoning which leads to a deeper level of learning, critical thinking and shared understanding. Rogers (2002) points out that Dewey considered collaboration to be a key characteristic of reflective practice. It is this discussion between students (inter-psychological) as well as the inner 'discussion' of a student reflecting on their own (intra-psychological) which Dewey proposed leads to higher order thinking (Shepel, 1999). Being 'better at evaluating my teaching' represented almost a quarter of all the reasons which the participants cited for their increased readiness to learn from placement.

It is clear from our findings that collaborating with peers provides valuable moral support and collegiality and therefore attends to the affective as well as the cognitive needs of the learner. Given that a number of studies have shown that anxiety before and during placement can impede learning (Hayes, 2003; Hurley and Hammack 2014) it is encouraging that the affirmation resulting from positive feedback from peers or video playback can provide a gentle and supportive introduction to classroom practice. Microteaching enables pre-service teachers to engage with the process of change and to explore the merits of taking greater control of their development. Establishing a culture of agency regarding professional growth is important given Mergler and Tangens' (2010) claim that student teachers' self-efficacy is established early in their teacher education programme.

However, Tekkumru-Kisa and Stein (2017) contest that science teaching does not improve from simply watching and reflecting on video recordings of practice. They claim the videos need to be carefully selected and embedded in participant-centered discussion which help learners take notice of key events within the teaching episodes. Our findings suggest that VideoAnt provides a straightforward and effective way of achieving this and adds significant value to each of the defining characteristics of microteaching.

Shortened teaching episodes- less becomes more.

We suggest that the close and explicit analysis of practice made possible by the interactive features of VideoAnt are best suited to the analysis of short teaching episodes. Firstly the time-marker, allows an exact teacher or pupil action to be identified and marked for discussion on the video timeline. The marker and comment facility serve as a microscope, drawing out the timescale and showing how the success of 'macro' aims of pupil learning intentions within a whole or a section of a lesson hinge on the effectiveness of the series and sequence of much smaller 'micro' actions on the part of the teacher. Secondly the annotation tool, in allowing the 'teacher' to make their thoughts on the particular incident explicit, provides access to the background information which may have informed and guided the teacher's particular course of action, or lack of action.

The reduction of the complexity of teaching is the core rationale for the use of microteaching in initial teacher education as it provides 'useful and rigorous ways of thinking and performing professionally before they are forced with the overwhelming complexity of the natural classroom' (Metcalf, 1996:272). Kennedy (2016) discusses the challenge of deconstructing practice and finding the right 'grain size', which is not so small as to create long lists of minutiae and yet not so large that novices have difficulty in 'seeing' the component parts of a lesson. We propose that the shortened lessons encountered during microteaching do not result in an overwhelming quantity of discussion points and makes possible a level of analysis which may not be feasible to sustain over a longer teaching period.

Video playback – from passive to active learning

Advances in technology have led to an increase in the use of video as a mediating agent for learning within teacher education. Research studies report on the many benefits associated with pre-service teachers analysing recordings of their teaching and reflecting on their own or peers' practice (Sherin and van Es, 2005; Rosaen et al. 2008). Martin and Siry (2012) provide an account specifically on science teacher education. It is the enhanced opportunity for observation, collaboration and objectification which make video a valuable learning tool in initial teacher education. Interacting with video, as opposed to merely watching, has been found to add considerable value to student learning. When students were required to edit video and/or add written commentaries, their learning was found to be more profound (McCullagh et al., 2013). The participants in this study reported thinking more deeply about their practice when they were required to add time marked annotations. This facility also extends the period of time over which learning can take place. Unlike a video clip which is essentially a record of the past, a VideoAnt may be considered to be a live document and a 'work-in-progress'. It provides the candidate with the opportunity to identify and acknowledge any areas for development in their practice or to elaborate further on their choice of actions.

Feedback- quality and quantity

Previous studies recommend that feedback is most effective when it is detailed (Mergler and Tangen, 2010; Benton-Kupper, 2001) and when it is provided by both tutors and peers (Napoles, 2008). Our findings suggest that VideoAnt allows for and extends this provision. Comments from peers often provided positive affirmation and help provide the conditions for the pre-service teachers to risk vulnerability and hold their teaching actions up to scrutiny and so, 'own up to the miscues in teaching' (Amobi, 2005:129). The facility to add personal annotation may create sufficient distance between the pre-service *teacher in* the video and the same individual as *observer of* the video, to realise that this is merely a critique of teaching and not of the person of the teacher. This conceptualisation of lesson evaluation is what Amobi (2005) suggests to be the first step in the type of reconstructuring which

results in growth and improvement. While practically all the participants felt that reading peers' comments was useful, 12 % were unsure of the value in responding to the comments of 'inexperienced' peers as has been reported by He and Yan (2011).

The pre-service teachers' comments on the feedback resulting from the use of VideoAnt characterise the elements of what Nicol and McFarlane-Dick (2006) propose constitutes high quality feedback. The time mark facility both 'clarifies what good performance is' and 'delivers high quality information' in the form of annotated video footage (Nicol and McFarlane-Dick, 2006:205). Being able to pinpoint exactly where in the teaching sequence they were going wrong, makes self-assessment easier and more fruitful for pre-service teachers and helps surmount the challenge of 'closing the gap between current and desired performance'. The use of VideoAnt within microteaching also addresses Brent, Wheatley, and Thomson (1996) recommendation that there should be sufficient time for feedback. The online facility enables participants to provide feedback at a time and place of their choice. Hoath (2012) observes that evaluations conducted immediately after teaching can often be overly influenced by emotion and general impression, rather than rational thought and evidence. Ellis et al (2015) found VideoAnt to be an effective means to facilitate self-evaluation but found that peer feedback usually consisted of praise with limited criticality. It is notable that a lower proportion of pre-service teachers found responding to peer feedback as useful as just reading peer feedback. Developing an evaluation template which brings about a deeper level of peer interaction is worth further exploration.

Conclusion

This study shows that pre-service teachers found microteaching to be a valuable activity for developing their skills and confidence in teaching primary science and increased their readiness for learning during school placement. They also reported that the interactive features of VideoAnt allowed for a more detailed and consensual analysis of their teaching. This enhanced level of individual and shared interaction with practice addresses the call, within science teacher education and teacher education generally, for a closer balance between theory and practice. In doing so VideoAnt adds considerable value to the potential for microteaching to, as McGarvey and Swallow put it (1986:46), 'help pre-service teachers to move across the bridge from methods courses to field experiences.'

The findings show that this form of microteaching can provide a valuable preface to actual classroom experience and allow for professional growth within the safe and theory-rich context of a university college. This could be of value in other subject areas where classroom experience may be limited by curriculum reform or policy. The synchronizing of teacher action (as it appears in the video) and the explanatory comment (accompanying annotation) provide a priceless insight into the otherwise tacit thinking behind a pre-service teachers' practice. This allows for feedback and guidance which is no longer restricted to the observable enactment of practice and facilitates a discussion based on more theoretical issues. In our future research we plan to explore how video annotation tools may be used alongside guided lesson analysis rubrics as a means of scaffolding the development of pre-service teachers' critical thinking skills and extending their concept of analysis beyond the simple dichotomy of 'good' or bad 'practice'. It may well be that where pre-service teachers' annotations provide a fuller account of the thinking which underpins their actions, the responses from peers may likewise be more critical and less affirmative. In conclusion we feel our study shows that microteaching, when coupled with an online video analysis too, may offer an effective way to develop the reflective and critical thinking of pre-service teachers and thus addresses the needs of 21st century science teacher education.

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