Reflective coaching of a non-specialist Physics teacher, using "Captured" Explanation

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Reflective Coaching of a Non-Specialist Physics teacher, Using “Captured” Explanation

Introduction

Thirty years ago, Millar(1988) discussed the training of non-specialists to teach physics. Survey results indicated that questioning, explaining theoretical ideas and doing physics demonstrations were experienced as difficult by the non-specialist. Hacker and Rowe(1985) identified substantial quantitative changes in teaching approaches and learning processes, when biology teachers taught physics and their classroom practice differed markedly to that exhibited by a specialist teaching physics.

The National Audit Office(NAO, 2016) reported in 2016 that 29% of the 1055 physics training places were unfilled in 2015/16. In addition 28% of physics lesson were taught by non-specialists in 2014. The DfE and IoP in 2015 claimed that around 1000 new physics teachers needed to be recruited each year for the next decade to meet demand.

I have been working for 14 years, on non-specialist physics knowledge booster courses, as part of an IoP initiative to support such teachers. These statistics indicate that we still have work to do helping non-specialists teach physics, nothing much has changed in 30 years.

The US national science education standards(Committee and Standards, 1996:63) require less emphasis on presenting knowledge by teachers and recitation by pupils and more emphasis on inquiry, discussion, debate and the continual assessment of understanding. The Framework for K12(Concepts and Ideas, 2012) has sections dedicated to modelling, constructing explanations, argument and communication. Millar in beyond 2000(2001) uses the term explanatory stories to capture presentation of ideas in good science teaching. He connects explanation with model use in science teaching and urges a wide variety of teaching approaches to be adopted. Osborne and Dillon(2008) in their report Science Education in Europe: critical reflections, stress an over reliance by teachers, on transmission pedagogy and short, triadic, discourse communication. They comment;

> *Little opportunity is provided for students to use the language of science even though there is good evidence that such opportunities lead to enhanced conceptual understanding. [p22]*

In this project a new reflective intervention strategy is described. This will address some of the aspects of physics teaching that non specialists find difficult. Working with the non-specialist will be an essential part of any plan to provide good physics teaching experiences, for a great number of pupils in the UK, for some years to come. This work will describe coaching techniques that may help build the confidence and expertise of the non-specialist physics teacher.

1. Literature review

In this section I will summarise key ideas from the literature that influenced and informed this project. I wanted to develop PPCK/PSMK in a non-specialist, using practical work to encourage classroom talk. A model based approach to teaching physics concepts was employed and I wanted to create a “reflective practicum”.

1.1 Teacher Knowledge

I am interested in developing physics pedagogical content knowledge, PPCK and physics subject knowledge, PSMK, in a non-specialist physics teacher.

Shulman (1986) discussed subject matter knowledge, SMK, pedagogical content knowledge, PCK and curricular knowledge. PSMK is an obvious concept but what PPCK means is subject to debate. Shulman argues that a teacher does more than transmit the propositional knowledge of their subject, PSMK. PPCK requires an understanding of PSMK and how physics ideas must be transformed, to become accessible to students. Lee and Luft (2008) show that PCK is difficult to define and that there are many conceptions of its nature. They identify seven key dimensions to PCK, that embrace Shulman’s original conception. Kind(2009) writes that PCK models focussing on **how** to teach abstract and difficult ideas, seem to be most useful. The knowledge quartet, KQ, (Rowland et al., 2005) identifies four essential knowledge dimensions and is a useful framework for talking about teaching knowledge when coaching a teacher. The KQ describes a combination of SMK, PCK it captures the essential meaning of the concept, knowledge for teaching. Loughran et al. (2004) introduced the notions of Content Representation, CoRe and Professional and Pedagogical experience Repertoire, Pa-PeR. The CoRe and Pa-PeR provide methods for representing PCK.

Hashweh (1987) concludes that teaching out of specialism results in;

(a) Non interactive teaching.
(b) Less range and depth to activities.
(c) A failure to spot misconceptions in pupils, often the teacher has the misconception.

He also introduces the idea of created critical incidents, designed to test a non-specialist teacher’s interactive teaching. Rowland et al. (2015) and Hurst (2017) also consider contingent moments, seeing them as powerful teaching opportunities. Borko and Livingston (1989) relate differences in the respective knowledge structures of novice and expert mathematics teachers, to their improvisational performances. Sanders et al. (1993) conclude science teachers working in and out of specialism show clear differences in the quality of their interactive teaching.

1.2 Practical

Hodson (1993) argues that pupils should be taught that theory and experiment have an interactive/interdependent relationship. Millar (Wellington, 1998:16) points out that school laboratory work can be limited as a learning activity. He emphasises its role as one of many communication strategies available to teachers. Abrahams and Millar (2008) develop a framework for analysing the effectiveness of practical work. They conclude that practical work should help pupils cognitively connect "objects" with "thoughts and ideas". Osborne (2015) and Millar (Wellington, 1998) argue that practical work is often not used to explore how the domain of ideas and objects interact. Encouraging interplay between observations and ideas is a key theme in this research.

Laws et al. (1997) and Mc Dermott (1996) produced US college physics curricula that made use of and developed new technology for use in physics practical work. Video analysis and data capture by computers, were essential classroom activities on these courses. In 20 years the technology has moved on, but its use in UK school classrooms is still rare. Sokoloff and Thornton (1997) talk about an interactive learning environment, where data captured from motion sensors informs learning. I have made use of this technology and combined its use with screen-casting[1] software, to capture explanation making by teachers I am coaching.

Animations are frequently used in the laboratory. PhET (University of Colarado, 2018) is a popular site for physics animations. These are often used as "practical laboratory" (Wieman *et al.*, 2008) minds on exercises and were used in this work in explanation screencasts.

1.3 Talk

The making of explanations and questioning dialogue are important classroom activities. Ogborn et al. (1996) develop a language for describing classroom explanations. They write, explanations;

(a) are stories that give an account of meaning making.
(b) don't convey ideas, they are the material you work on to make ideas.

These ideas underpinned this research project.

Van Zee and Minstrell (1997) comment that questions are often used by the teacher to evaluate what students know. The paper examines how Minstrell used question sequences to work with pupils on developing explanations. The notion of "reflective discourse" emerges as an extended series of questioning exchanges. Mortimer and Scott (2003), Table 1.1, present a framework for analysing science teaching interactions. This is one of the frameworks used to interpret data in this project.

[1] Screen casting software captures all your interactions with your computer screen, annotation, pointing as you talk. It renders the data as an MP4 file. In this project I used "Explain Everything" https://explaineverything.com/.

<table>
<tr><td>Focus</td><td>PURPOSE: working on ideas, setting a problem, physics model development</td><td>CONTENT:
(description, explanation{models})
(data, theoretical)</td></tr>
<tr><td>Approach</td><td colspan="2">COMMUNICATION:
(a) Interactive/dialogic
(b) Non-interactive/dialogic
(c) Interactive/authoritative
(d) Non-interactive/authoritative</td></tr>
<tr><td>Action</td><td>PATTERNS:
I Initiate
R Response
E Evaluate
P Prompt
F Feedback
IREIRE associate with (c) (d), closed triadic.
IRPRP (a) (b) Open and closed chains
IRFRF (a) (b).</td><td>INTERVENTION:
(1) Shaping ideas
(2) Selecting ideas
(3) Highlighting essentials
(4) Sharing ideas
(5) Checking Understanding
(6) Reviewing</td></tr>
</table>

Table 1.1 Analysis framework, adapted from Mortimer and Scott 2003 and Scott et al. 2005.

Aguiar et al. (2010) conclude using this framework that questioning provides pupils the opportunity to connect scientific ideas with knowledge. Scott et al. (2006) point to the "tension" that exists for the teacher, between supporting classroom dialogue and establishing propositional knowledge using an authoritative approach. They emphasise that pupils need the opportunity to talk science and make the language their own. Teaching for learning requires shifting between authoritative and dialogic talk phases. A crucial first step is identified;

> *(need to) provide tools which allow teachers to reflect upon then modify their classroom practices.*

I develop such a "tool" in this project.

Chin (2006) using the Mortimer and Scott framework, found that where the F move in IRF dialogue embeds a further question (a reflective toss) deeper thinking by pupils was provoked. Chin (2007) discusses using a series of questions to prompt and guide pupil thinking. This technique was important in this project.

1.4 Models

Hillier (2013) discussed the notion of coherent internal account, CIA. ITT students' explanations were analysed and interview data used to determine if their SMK/PCK was changed. Hillier claims that developing a CIA helps transformation of SMK to PCK.

I tried a model based approach to physics teaching with teachers, in an effort to develop a CIA more efficiently. Wells et al. (1995) explain a conception of the modelling method applied to high school physics teaching. Brewe (2008:1156) contrasts modelling with the standard teaching approach .

1. Models are built using laws versus laws are given as equations.
2. Representational tools are used to build models; these tools can then be used to solve problems versus quantitative problem solving using equations.
3. Modelling is a process that is learned through accumulating experience verus problem solving involves learning tricks and skill developed with solving lots of problems.
4. Models are distinct from phenomena they represent versus content and phenomena are indistinguishable.

PSMK was delivered via a modelling approach in this project. I believed this method would allow me to concentrate on CIA development, because in developing a model you have to pay close attention to phenomena that need explaining.

Chi et al. (1989, 1994) examines self-explanation, generating internal explanations. These papers show that such activity promotes integration of new ideas into existing schema. I wanted to bring ideas from this literature to bear on the problem of developing CIA in non specialist teachers.

1.5 Coaching/ Mentoring

Coaching and mentoring are complex activities whose purpose is to support individual learning. (Rhodes and Beneicke, 2010) Upson Bradbury et al. (2007) argue that a mentoring relationship involves reflective practice. Nilsson and Van Driel (2010) emphasise listening to ideas and thoughtful feedback as ways to ensure supportive interactions in mentoring. These authors used "stimulated recall", SR, to encourage reflection on practice by participants in mentoring research. Calderhead (1981) and Stough (2001) discuss the methodology of SR. The main criticism of SR is that you cannot be certain that what is uttered under video stimulus, is what a teacher was thinking at the time (Yinger, 1986). I decided to develop the technique into Video Stimulated Reflection, VSReflection. In this project, I am not interested in what the teacher was thinking at the moment considered. I want them to think deeply about what the video content is saying to them now.

Crasborn et al. (2011) create a 2 D model that captures the active/reactive and directive/non directive dimensions of mentoring. Individual needs are addressed, when the mentor can change their approach using the entire 2D mentoring plane. Feiman-Nemser (1998, 2001) explores mentoring tactics in detail and describes educative mentoring, helping mentees to learn from their practice. Professional relationships in peer coaching/mentoring are built on trust and mutual respect. This takes time.

Mackinnon and Erickson (Grimmett and Erickson, 1988:113-137) use Schon's coaching models (1987),

(a) Follow me
(b) Joint experimentation
(c) Hall of mirrors

to analyse dialogue between coaches and teachers. They capture the essence of the reflective practicum and this is what I wanted to recreate and develop in this project. In his PhD thesis (Mackinnon, 1989:118) explores the three Schon coaching models within a reflective practicum, Fig 1.1.

The figure originally presented here cannot be made freely available via ORA because of copyright. The figure was sourced at Mackinnon, A. (1989) Conceptualizing A 'Reflective Practicum' in Constructivist Science Teaching. University of British Columbia, p119.

Fig 1.1 Reflective Practicum (Mackinnon, 1989:119)

The supervising teacher, SpT, and student teacher, StT, consider classroom events and any relevant interactions, the practicum phenomena. The SpT and StT have different background knowledge and experience and so frame the data in very different ways. The practicum objective is to bring supervisor and student "closer together", so the student acquires PCK. I like to think that demonstration and imitation arrows, Fig. 1.1, are linking knowledge domains (Clarke and Hollingsworth, 2002) and this is achieved by coaching using the three Schon techniques. Mackinnon through coding of data, develops clue structures, to identify each coaching method.

(a) Follow me; PCK is modelled by coach (SpT) and the coach leads on the interpretation of classroom events and determines what needs to be learned. Reflection leads to coach changing practice then back to reflection. Teacher surfaces confusions and coach displays genuine interest.

(b) Joint experimentation; The teacher occasionally takes the lead during reflective enquiry with coach. The student teacher can say what they want to produce in the classroom.
(c) Hall of mirrors; The coach models practice as that practice is being discussed. The coach interacts with teacher in the same way he wants teacher to interact with pupils. The teacher is brought to an appreciation of how the pupils understand the subject matter. Practicum mirrors classroom.

These ideas helped me to develop clue structures within the CH framework I was using. I attempted to capture the essential features of the "reflective practicum" in my use of the CH framework.

1.6 Reflective practice and Teacher Growth

Korthagen et al. (2001) discusses realistic teacher education. The "ALACT" model captures the essence of reflective practice and was a model that I used extensively initially. Korthagen et al. (2001:65) discuss Action Research (the adopted methodology for this work), AR, pointing out its similarity in approach to the notion of reflective practice embodied in the ALACT model. Proponents of AR view learning as active production of understanding rather than reproduction of transmitted knowledge, in line with realistic teacher education. Clarke and Hollingsworth (2002), CH, introduced the notions of change sequence and growth networks, as well as the framework which I now use to design and evaluate teacher education sessions. Fig 2.2.

The figure originally presented here cannot be made freely available via ORA because of copyright. The figure was sourced at Clark, D. and Hollingsworth, H. (2002) 'Elaborating a model of teacher professional growth', *Teaching and Teaching Education,* 18, pp. 947–967

Fig. 1.2 CH Framework (Interconnected Model Teacher Professional Growth IMTPG)

The CH model captures how the knowledge domains of the teacher are modified through interaction with an external knowledge domain. In Fig 1.2, circular domains represent changes to teacher knowledge, PPCK, PSMK perhaps and these changes are brought about via reflection and enaction. The web of links has a temporal order, but captures too the complex development of ideas and values which is not linear.

In this work the external domain, is where PSMK models are explored, experimental skills developed and coaching to support physics teaching, occurs. Reflection (d) on this experience can lead to change in the teacher's values and knowledge. VSReflection techniques are also employed. The teacher interacts (c) with the external domain and can change its content/domain activity, through such interaction. The external domain knowledge and personal domain values and knowledge, result in ideas being enacted (e) (f) in the domain of practice. Enaction implies the belief in and assimilation of, ideas that are consciously put into action. PPCK is modified and developed in the domain of practice. Reflection on and in action (h1) (Schön, 1987, 1995) in the domain of practice, change the teacher's personal domain values and knowledge further. Some data from the domain of practice will be subject to further reflection (h2) and will become salient, further reflection (h3) (h4) modify the personal domain content and the significance of salient outcomes . Salient outcomes may affect behaviour in the domain of practice (g) before reflection on action (h3) (h2) (h1), Fig. 1.2. How reflection links are inferred is an important methodological issue, because I want to help teachers develop growth networks. Mackinnon's (1989) notion of "clue structure" (p 7 above), helped with this work. Essentially the idea was to define what statements in the data, "clues", might allow me to infer reflection had taken place.

Justi and van Driel (2005) used the Clarke et al. (2002) framework to measure the development of chemistry teachers' knowledge of models and modelling. Witterholt et al. (2012) describe a similar project to assess the knowledge growth of a mathematics teacher. These papers provided insights into how the CH framework could be used to design and assess interventions.

I have used the term reflection a great deal. Dewey (1997:36-37) writes in detail about soap bubble behaviour observed during washing up. I used this narrative with data captured from a pressure sensor, to discuss the meaning of reflection, before coaching began. Dewey identifies important steps in reflection; defining a problem, positing a solution, exploring the solution by reasoning and further data collection to confirm belief in solution. The intervention to be discussed below, comprises the following essential elements; practical demonstration, discussion and use of models to make explanation, I call this DDAME, Fig.3.11.

Russell (2005) believes reflective practice can be taught. Discussing reflection in and on action (Schön, 1987, 1995) Russell gives examples of how reframing can lead to a new course of action. Calderhead (1989) describes how surprising "back talk" can lead to reflection in action. Mackinnon (1987) deals with detecting reflection in action in research data. He points out the important distinction between acts of reflection and acts of rationalisation. The concept of a "clue structure" essentially definitions/codes, to be used in looking for reflective episodes in the data, is developed and proved useful in my work. Mumby (1989) thinks of Schon's "back-talk", (unexpected feedback providing puzzles and surprises), as causing the teacher to be taken aback and this interpretation was useful to me in this project. He argues that reframing stimulated by back-talk, is like a gestalt shift. Reframing changes the way we look at data. Reflection in action leads to reframing, reflection on action is the process of thinking again about old, often unsurprising data. Appendix 1.A contains an account of an example of my reflection in action.

2. Roger and Nicola: Perspective and Insight

Roger and Nicola[2] were essential to the development of the AR cycles described in this work. I devoted much time to analysing data taken from observing their practice, whilst working with Michael (3.2), the non-specialist physics teacher considered in this work.

I analysed a great deal of data, so will summarise key findings here and present details in appendices for background only.

I wanted to study the practice of an expert and complete novice to obtain insights that could inform my work as a teacher educator, TED, with Michael. This parallel study proved very useful.

Roger is an experienced physics teacher and head of department. He is a colleague I collaborate with on other AR projects. I used him to try out analysis techniques and to gain insight into my own interactive/dialogic teaching practice where explanation and using data is emphasised. Nicola was an ITT student, who attended my summer 2017 physics booster courses. Like Michael she had A level physics, but studied business at University. I tested my ideas on packaging physics into models and teaching the use of the explanation capture software on Nicola.

2.1 Roger

Studying Roger allowed me to think about the developing discussion aspect of my teaching approach with Michael. I wanted to answer, at least tentatively;

> (R1) What are the problems, if any, of working for long periods in interactive/dialogic (Mortimer and Scott 2003) mode?

I revisited a lesson on pressure which I had discussed in assignment 2 (Author, 2017a). A new, substantial analysis which uses Schon's ideas on reflection (1987, 1995) is included in appendix 2.C. In this lesson I observed Roger working with a class on a predict, observe, explain, POE (White and Gunstone, 1992) problem for 9 minutes. He had to reflect on the backtalk from the pupils and adjust his teaching accordingly. Open interactive dialogue threw up many ideas that needed careful consideration and this was time consuming. Many of the class had the right idea early on, so may have been bored by this protracted discussion phase.

I discussed a motion lesson with Roger, identical to the one Michael delivered. Appendix 2.A. This greatly informed my motion coaching session with Michael. Interview data helped me think about the research question (R1). I was already using the term "cognitive noise" to describe the flood of ideas interactive dialogic teaching leads to.

[2] All names pseudonyms.

Interviewer: *Now, what I really loved, is there was lots of discussion going on. You were dealing with lots of different questions and different ideas. Did you feel that some of the ideas that were being thrown at you were taking you away off course and ruining the flow?*

Roger: *Yes, a little bit. But we know it often happens. Its' a balancing act between dealing with those satisfactorily….*

Interviewer: *As a very experienced teacher, how do you control that to avoid, what I'm calling, "cognitive noise"?*

Roger: *One of the difficulties it poses is that, with me leading the discussion, everyone has ideas they want to get out and test and I can't really deal with all of them. Someone will say something and then someone shouts out. You saw it in that lesson, they correct each other. You give them that chance to test ideas out, to correct each other. We'll then have a feedback, a few minutes, and then you'll get ideas of better quality.*

Roger also taught Lenz's law, which again helped me with coaching Michael. Appendix 2.C. Again there was lots of cognitive noise. Roger's extensive PSMK and the fact his pupils expected interactive dialogue could account for this. Returning to (R1) the problem with dialogic teaching is cognitive noise. I needed to consider this issue when working with Michael.

2.2 Nicola

Appendix 2.D contains analysis of two coaching/reflection sessions I carried out as part of a longitudinal study on Nicola's CIA (Hillier, 2013) of mechanics and electricity. I wanted to examine how Nicola used video/data synchronisation techniques. I now consider audio data from a reflection session in December 2017.

Nicola was talking about explanation capture/reflection work she had completed with me, on the summer booster course.

Interviewer: *How did you feel about this exercise? (VSReflection)*

Nicola: *I really liked this. I liked the fact that you could visualize what is happening at the same time as seeing what happens on the graph. The school I'm at now, working at now I guess, they're getting Chromebooks in September and a lot of the staff aren't actually that keen and they're like, "Oh what's the point? Why? We don't need that." I keep telling them about this specific activity and they have data loggers and they have all this stuff. They really can use it and I keep telling them, "Oh, we did this thing at my residential that we had the car and it showed the distance-time graph and then we could change it to a speed-time graph. It showed in action and it made really clear." Because there's a lot of non-physicists, in fact, there is only one physics teacher in this whole science department and so they were struggling with that and I'm just like, "It's perfect. It will help you out, it will help the kids out just to see* *exactly what happens when it stops, when it reverses. It's like all this. You could just mess around with and see the live action along with what happens with the graph."*

This was a surprising response. Nicola believed in the power of video/data synchronisation and she was confidently talking about its use, to more experienced teachers. This encouraged me to really emphasise the technique with Michael when coaching.

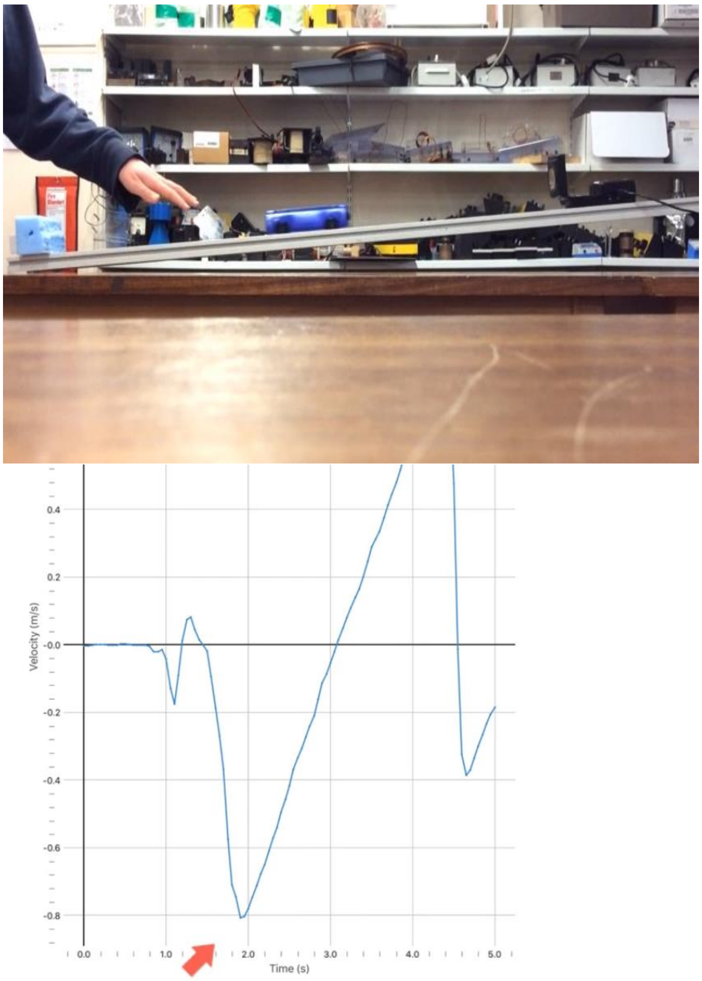


Fig 2.1 Synchronising video/data

Appendix 2.D describes how the technique works in detail. The full "multimodal" explanation capture "video experience" is needed to appreciate its full potential as a coaching tool. In Fig 2.1, I show a video frame selected to illustrate the instant when a hand is removed from pushing a cart. Nicola has identified, using a pointing tool (red arrow), the position on the v/t graph that coincides with the video frame. Audio narrative and sometimes further annotation, for example force diagrams can be added to make a full explanation. Nicola provided key insights that informed the explanation and model work with Michael.

3. Methodology and Intervention

In this section I first discuss the action research methodology chosen for this work. Then Michael is introduced and I frame my research questions. Finally three cycles of action research with Michael are analysed.

3.1 What is Action Research, AR?

AR can be defined as a systematic study, involving repeated cycles (Fig. 3.1) of classroom action and reflection on the outcomes of the action (McNiff, 2013:61). Reflection is at the heart of the AR process. Conclusions drawn after reflection, allow decisions about the content of each phase of the cycle to be made. The objective is to change teaching practice. McNiff (2016:20) emphasises that the main features of AR include commitment to reflection, knowledge generation, collaboration (everyone's view counts) and practice transformation.

Action research can be viewed as akin to reflection in and on action (Schön, 1987, 1995) The "in action", describes the research of a teacher working in isolation and the "on action", captures the essence of the "teacher researcher", working collaboratively.

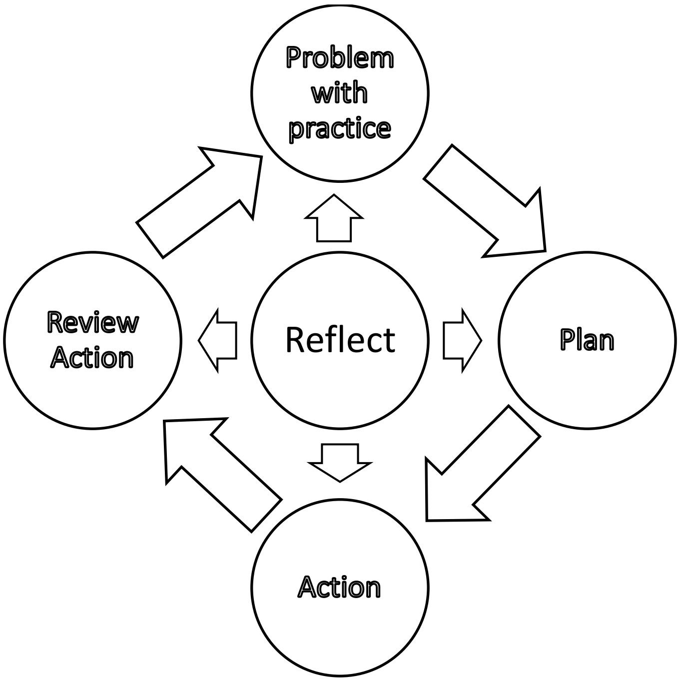


Fig 3.1 AR Cycle Adapted from (Cohen *et al.*, 2011:355).

The notion of reflexivity is important because researchers are also participants in the AR cycles. Researchers have to be conscious of the effects that their values, perceptions, attitudes and feelings[3] are having on the way data is collected an interpreted as part of their AR project.

I needed multiple data sources to be convinced that my claims about knowledge growth were sound, Table 3.0.

Field Notes	Video	Captured Explanation	Interview
Were taken during classroom observations. These helped the framing of reflection topics.	Video of teaching was taken and edited into episodes for VSReflection.	Screen capture application was used to produce explanations for reflective discussion. This was a source of VSReflection too.	Interview data pre and post lessons and coaching sessions was taken.

Table 3.0 Data Sources

Action research has a well-defined methodology for data creation from such sources. Data are used to create accounts of events and these accounts are interrogated to produce processed data and eventually evidence (a controversial step in qualitative research) to support claims as to the effectiveness of an intervention. Multiple sources can allow triangulation to be employed, in an attempt to improve the validity of the data. There seems to be no methodology for the interpretation of qualitative data(Winter, 1982). I cannot claim, my extensive data set represents the PPCK/PSMK of every non-specialist physics teacher. The validity of my project claims is an important question to be answered if this work is to persuade others to consider using this model of a reflective practicum. Whitehead(1989) offers help on judging the validity of a claim;

(a) Did the enquiry utilise an AR cycle?
(b) Are the assertions made clearly justified?
(c) Is there evidence of a critical and enquiring approach?

AR remains the most appropriate methodology for this project, even given the interpretation/validity problem. A positivist, physical science approach, attempting to control variables and utilise theory for interpretation and explanation of data, would have been preferred. Such an approach was impossible because a key dimension of the problem concerned social interaction in the classroom, variables are numerous, impossible to control and no theory exists to analyse this complex system adequately. A mixed methods methodology was considered, but I did not want to collect statistical data from pupils at this stage given the time constraints for project completion. Mixed-methods is a common methodology in the physics education research literature. Importantly for this project and notwithstanding the limitations of qualitative data interpretation, AR has a reputation for

[3] Guaranteeing anonymity, protecting data and ensuring each teacher had freedom of expression are important ethical issues. I ensured they did not feel coerced into adopting my values.

producing working theory, useful insights and tangible outcomes, of practical use for teaching and learning.

The data below was analysed using the IMTPG (2002) and the classroom dialogue framework, Mortimer and Scott(2003). Researcher/collaborator values inevitably underpin data interpretation. Triangulation between data sources wherever possible mitigated researcher bias. The key notion of reflexivity was explicitly considered when drawing conclusions.

Below I discuss the AR cycles; their evolving structure will become apparent as will the roles of IMTPG and DDAME. DDAME(demonstration, discussion and using models to make explanations) summarises the underlying focus and physics TED approach of the intervention. Michael wanted help in the use of practical demonstration to encourage open discussion with pupils and develop explanations collaboratively. I used demonstration with him to set up a reflective practicum. I deployed models to help with his assimilation of physics and to help him generate explanations. The idea was through seeing things my way (Schon 1987), he could work in an identical way with his pupils. In Fig 3.11 below, I show how the analysis of captured explanation and VSReflection data, can be employed, to justify/claim links in the IMTPG. The IMTPG forced me to focus on reflective coaching during AR cycles and its critical evaluation using data. The summary icons and associated clue structure/data inferences tables, portray Michael's evolving knowledge structure as a result of DDAME. They are what I used to address the main research question.

The novelty in this work was how explanation (multimodal) data was captured (using "explain everything" app) and utilised to create the reflective practicum.

I developed a coding summary used throughout discussions of data, to connect inferences from analysis of data to the IMTPG. It is important to refer to the tables, which define IMTPG links and the summary icons, as each piece of data, Table 3.0, is discussed and coded.

I will illustrate the process behind the assignment of the data codes, by considering an example of the analysis. It is important that the method is clearly understood.

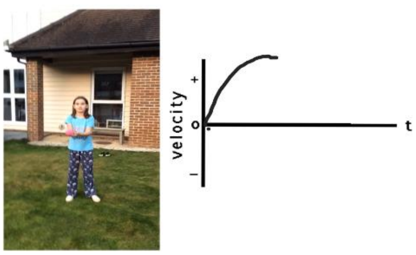
Code T3.2[1+2] see page22 below. The code refers to data inferences, Table 3.2, supporting assignment of links 1 and 2 in IMTPG. So the data and analysis together allow existence of a link to be inferred. Table 3.1 gives the clue structure used to think about link meaning in the context of the AR cycles.

This example code was assigned after consideration of VSReflection1 data. Michael had produced an explanation of a ball thrown into the air. The explanation was captured using the "explain everything" software. I had looked at the video and prepared the coaching activity to follow on from our VSReflection1.

	Definition of Link
1	Michael’s **existing** SMK/PCK leads to questions and discussion. VSReflection 1 helps.
2	Michael reflects on tutorial episode and develops PSMK/PPCK.
3	Tutorial experience influences class room behaviour.
4	Michael’s **modified** PSMK/PPCK influences class room behaviour.
5	Michael’s PSMK/PPCK changes on reflection on practice. Aided by VSR2 and post lesson interview.
6	Reflection on lesson data determines salient outcome.
7	Previous or new outcomes affect teaching. All reflection data important.
8	PSMK/PPCK modified by reflection on outcomes.
9	Deciding after reflection what is salient using PSMK/PPCK.

Copy Table 3.1

Above is a copy of Table 3.1 which shows the clues to identify the existence of links in the data, allowing an ssignment in the IMTPG. These definitions based on the work of Justi and van Driel (2005). Link 1 captures the notion that Michael is interacting with external coaching domain, to change its content. His explanation is providing “material for us to work on” (Ogborn et al. 1996:15) in the VSReflection1 process.



Copy Fig 3.2

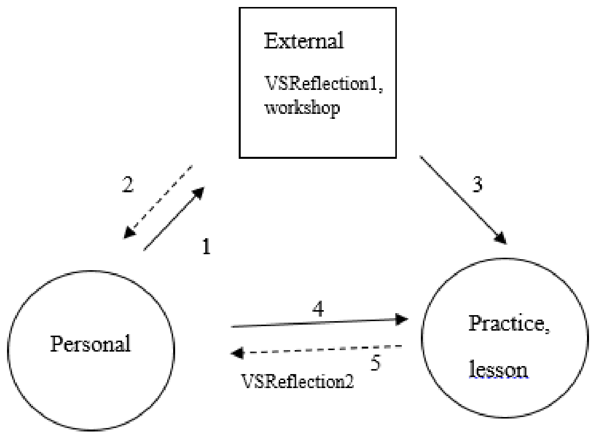
“At the top the ball is at rest”.

The quote and the image from his video data allowed us to focus in on the process by which he made the explanation and the error he had made in the narrative. Looking at link 1 in Table 3.2 copied below, I was confident that Michael;

(a) Was thinking and asking questions during the reflection process,
(b) Purposeful discussion was allowing him to resolve the misconception and see that this might be how some of his pupils would think about this problem.

	Inferences from Data
1	Michael's **existing** SMK has been found wanting. VSReflection1 has led to Michael voicing questions and discussion of his misconceptions.
2	Michael reflected on tutorial and VSreflection1 as evidenced by excellent questioning episode in lesson. Some pupils had avoided his misconception, so Michael had a better understanding of the constant acceleration model, underpinning his teaching.
3	He used data-logging and the capture explanation technique in his lesson.
4	He was more dialogic during questioning episode about gradients of v/t graph. He was exploring ideas with pupils.
5	In VSReflection2 Michael reflected on what was a new physics teaching experience for him. He understood the pupils misconceptions because he had the same ones and now he knew how to address them in a classroom situation.

Copy Table 3.2



Copy Fig. 3.10

At this stage I started to draw the IMTPG icon, see above. Fig. 3.10. Link 1 is saying that changes in the external domain were brought about by Michael enacting ideas from his personal knowledge domain. The external domain is where I coach, and activities created in this domain, should encourage reflection.

As Michael resolved the conflict between the graph peak and the claim that the ball was at rest, see figure above, I can infer the existence of link 2, Fig. 3.10.

You will see these codes deployed beside analysis remarks under sections of data in what follows. This process of making inferences from data was followed throughout this work.

3.2 Michael

Michael is an experienced biology teacher and head of science in a local comprehensive school. He does all the physics teaching. I have worked with his school for many years. I have examined Michael's teaching, learning and NOS beliefs using the Tsai(2002) classification. (Appendix 3.E). During this work, in 2016, I observed several hours of him teaching energy and electricity to year 10.

I know Michael well. I respect his teaching and learning beliefs and values. We are collaborators and have developed a good coach/mentor relationship, which will become apparent. His strengths are clear to me. The intervention to be described here, arose because Michael wanted to become a more confident physics teacher. He had a definite question, how do I become more confident when dealing with physics questions in class?

I have analysed in previous assignments(Author, 2017a) some dialogue in a lesson where Michael is teaching circuits. (See Appendix 3.A for modified full episode transcript)

1. *"Can anyone explain why it might be dimmer when there are two bulbs?" Michael asks.*
2. *Pupil 2 replies," because it sharing out the same amount of power as before but between two bulbs."*
3. *Michael interrupts before answer finished, Pupil2 is using the word Watts but his dialogue is lost… "You keep using the word power,*
4. *Pupil 2 interrupts with the word "electricity "*
5. *"can I just warn you that it has a very specific meaning…." Michael adds, "can we avoid using the word power today and we'll come onto power later."*
6. *"Let's talk about it in terms of energy," Michael urges…*

This section was important to me as researcher, because of Michael's reaction to pupil 2 move 2. Michael is quick to see the dialogue moving away from his plan for the interaction and move 3 he is closing down any further exploration or working on ideas by him and the class. I make this claim on the strength of many hours of observation. It is indicative of Michael's pattern of communication in physics teaching. He moves from dialogic to authoritative mode (Mortimer and Scott, 2003) very quickly. Move 4 the pupil is still working on the answer, by move 6 Michael is in control. This was a golden moment in this lesson to explore, electricity, power/energy and make connections between the concepts. Hashweh (1987) acknowledges that this pattern of discourse is typical of the non-specialist teaching outside their subject area.

In this short episode Michael wants to discuss the lab work. The IRE(P) patterns (Table 1.1) are indicative of non- interactive/authoritative communication approaches. (Mortimer and Scott 2003) This approach gives the teacher control of the classroom social plane. Michael can stick to his plan. There is little room for pupils and the teacher to work on ideas.

It may be that IREIRE…with E replaced by P(rompt) moves when needed, short dialogue patterns, suit this class better than more interactive/dialogic communication (Mortimer and Scott 2003). I believe however that this pattern of short dialogue is symptomatic of Michael's lack of PSMK/PPCK. In the post lesson interview he stated that he felt "just a little bit ahead" of the pupils.

In the two hours of electricity teaching I observed, there were lots of activities, practical and work sheet based. Interaction was carefully managed by Michael. There were no phases of interactive/dialogic discourse. (Mortimer and Scott, 2003).

Michael always has a plan which he meticulously implements. I asked him about his planning for physics lessons.

> **Michael**. *I look to ensure that I am covering the right specification points. I use the scheme of work to ensure I am covering the right material, not missing anything. I then try and think about the way I would explain those points. I try to think back to my own time when I was at school, sometimes, to try and think about things that helped me to understand principles.*

Michael wants to explain concepts clearly and he can appreciate the difficulties his class are having with physics ideas, this is a real strength. Michael does not however, take time to explore ideas with pupils, because he feels unsafe with such activity. There is a "tension" in his physics teaching, because he wants to explore and explain. Relieving this "tension" is the objective of the AR intervention described in this report.

Michael uses models frequently because of the many references to modelling in his scheme of work, but also because he understands physics better with non-mathematical models. I concluded that packaging physics into models would be a good way to discuss concepts in the coaching sessions planned for the AR intervention.

> **Michael**. *As I am not a physicist myself, I don't always think of it… I know some physicists think of things very much in terms of maths and that helps them to explain, that language helps them to explain. I've always found it easier to think of models like the bike, it makes much more sense to me and so I think I always do it that way around. I know some physicists do the maths first.*

Michael used a bicycle chain model to discuss energy transfer in electrical circuits but he also likes to use computer models, particularly those produced by PhET.(University of Colarado, 2018)

Michael. *The PhET I used because I think it gives a really visual…. I think that's why the bike stuck in my head, whereas when you have an animation you take it to another level and you can visualise quite clearly the concept we are talking about.*

Michael likes to use technology, he wants to explain clearly and understand. Developing a CIA (Hillier, 2013) of physics concepts is important to him.

I wanted to find out how he felt when facing tricky questions from pupils. I knew from classroom observations, that moments of contingency, were not used as golden opportunities to develop pupil understanding and confront their misconceptions.

Interviewer. *Do you ever think about the difficult questions that might come up in a lesson and how you would deal with them?*

Michael. *My issue is again as a non-physicist is my subject knowledge does not go much further than the kids. So if I start to get difficult questions I am in trouble. I did A level physics in 1992 and that was my highest level.*

This was an admission that inspired me to develop this AR intervention. Talking about how Michael wanted his physics teaching to evolve, was important.

The analysis of data collected in 2016 early 2017, illustrated above, and my talks with Michael, lead to the following research questions.

M1. In what ways and to what extent is Michael's PSMK/PPCK developed by the intervention (reflective practicum) AR cycles?
M2. Is there evidence to infer development of a CIA and growth network?

I discussed the AR intervention with Michael following my trial workshop (2017) of the screen capture techniques to be employed. He agreed to the proposal and ethical issues around filming in the classroom were worked out satisfactorily. We had to confront some of his current teaching habits, bringing about change to his knowledge domains, (Clark and Hollingsworth, 2002). The work had to be done without imposing change or undermining his confidence, key ethical issues.

3.3 Motion: AR Cycle 1, AR1

I began this series of AR interventions by working with Michael on a motion and mechanics teaching sequence. I asked him to produce an explanation of the motion of a thrown ball, using the explanation capture application.

3.3.1 Reflection on Captured Explanation

I used ideas from the workshop, April 2017 with ITT physics “booster” students (Outline, Appendix 3.B) and from work with Nicola (2.2). This first AR cycle was designed to help Michael develop essential PSMK, but also show him how effective demonstration, using video motion analysis and data logging, might improve his PPCK in this area, Fig. 3.11. I needed to do this in such a way that he did not feel “put off” by his lack of physics knowledge. I also had to convince him that the technology being introduced, would help him develop PSMK and PPCK in future cycles, the knowledge growth concept, (Clarke and Hollingsworth 2002). Finally, I needed to build his confidence so that he would feel able to try these techniques with his own pupils.

I spent some time analysing Michael’s ball motion explanation, VSReflection1 data. It was apparent that Michael, although being totally convinced by his explanation, had several serious misconceptions. It was encouraging however, that despite this being a first attempt at using “explanation capture” software, he was using data/video synchronisation techniques (Nicola 2.2).

I consider now the VSReflection1 data. (See Appendix 3.C for full data summary.) The images in the figures below, show a video frame and a graphical image that is developing along with Michael’s accompanying video narrative. (The method behind the analysis of the following data was discussed fully above.)

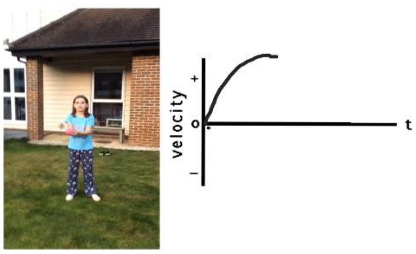


Fig 3.2 Using video/graph synchronisation.

Michael,

"At the top the ball is at rest".

This however is not what the graph is saying. T3.2[1+2]. The video narrative is heavily influencing what he is drawing on the v/t graph. This is a common problem in the classroom, nicely exposed by this technique.

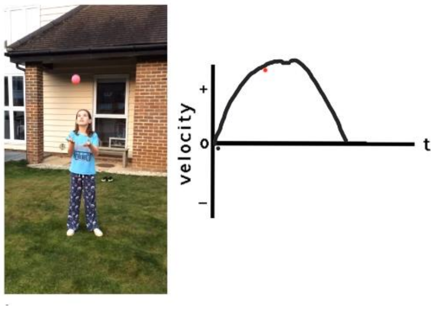


Fig 3.3 Pointing tool

He uses the pointing tool (red dot) to indicate at the peak of his graph, the ball is at rest. Fig 3.3.

> *"We can follow on the graph the movement of the ball, at the very top there is no velocity".*

He synchronises the video to the graph using the pointing tool T3.2[1]. Michael is not thinking about the graph he is drawing.

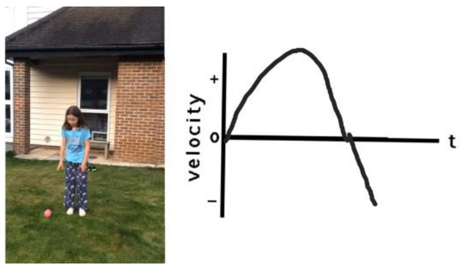


Fig 3.4 Moving down

> *"When it goes past the starting point (the release point of the ball) the velocity is negative".*

His idea of negative velocity, Fig 3.4, is completely erroneous. T3.2[1].

There is much more of interest in this data and we looked at it all during the VSReflection1 session. In the first part of my coaching meeting with Michael, I used my analysis of his explanation, illustrated above, to guide my dialogue with him. I played his explanation back and conducted an interview, to obtain further reflection data. I tried not to lead, but used the video data to stimulate him to reflect on key parts of his explanation, "VSReflection". I wanted him to see the power of the technique, but also to learn about thinking aloud(Chi *et* *al.*, 1994) as you study physics and to see how my practice **with** him could be mirrored in the classroom **by** him.(Schön, 1987, 1995)

I ask about the first part of the video.

1. **Michael.** *When she initially threw it and she's applied the force to it, then you have the greatest acceleration, but then as it -- because of the opposite force of -- well, there is gravity pulling the ball back down to the ground. There's initially a resultant force when she throws it, but then as it goes up through the air, it loses some of the kinetic energy as it lost, or convert it to the gravitational potential energy as it gains height. When all of the kinetic energy is being converted to gravitational potential energy, or as that's happening, the acceleration, the rate of acceleration slows down until its zero. Then all of the energy is effectively stored in the ball as gravitational potential energy. That's converted back to kinetic energy, it starts accelerating back towards her hand.*

He is using energy models and forces models, but linking his narrative to the v/t graph. I ask about resultant force direction.

2. **Michael.** *Initially when she throws the ball, there's going to be the force of her that she applies to the ball. Effectively, counter balanced by the force of gravity pulling that down, there is a resultant force there. That gives the ball, then the ball because there is an imbalance force that causes it to accelerate.*

He is trying to use F=ma.T3.2[2].

3. **Interviewer.** *Then when it leaves her hand-.*
4. **Michael.** *There is no force there.*
5. **Interviewer.** *There is no pushing force.*
6. **Michael.** *No.*
7. **Interviewer.** *But are there other forces?*
8. **Michael.** *Well, there is gravity, there is air resistance.*
9. **Interviewer.** *Which directions do they act?*
10. **Michael.** *The gravity will be pulling it back down towards the earth, the opposite direction to the throw. Air resistance is just acting as its moving through the air, the particles of the air are resisting it, its pushing it backwards, they're slowing it down which is why its loosing. The ball has momentum I suppose, it's been thrown and its losing speed because -- the kinetic energy of those resistive forces pushing back in the other direction.*
11. **Interviewer.** *Which direction is the resultant force when it leaves her hand?*
12. **Michael.** *When she actually throws it, when she's applying that force initially-*
13. **Interviewer.** *When it's left her hand, it's in the air, which direction is resultant force?*
14. **Michael.** *Well, the only forces acting on it gravity pulling it back down.*
15. **Interviewer.** *All right, so which direction is the resultant force?*
16. **Michael.** *Down.*
17. **Interviewer.** *Which direction is it accelerating?*
18. **Michael.** *Up.*

I realise now that have to work on exactly how F=ma can help us to draw the correct v/t graph, a feeling vindicated in the next exchange.

19. **Interviewer.** *Okay.*
20. **Michael.** *No, it's not, it's slowing down and it's negative. It's slowing down, it's a negative acceleration, is it? I don't know, I'm getting confused, this is [laughs]*

Michael by reflecting aloud is realising he is confused. Move 2 told me I needed to develop the model of constant acceleration using Newton's 2nd law, so Michael would feel confident using it. The VSReflection technique helped me to pinpoint PSMK issues for addressing in the coaching session. Moves 17, 18, 19 and 20 confirm this assessment. Move 21 was important, I needed to follow up on his confused state immediately.

1. **Interviewer.** *Okay, we're now looking at the two-minute mark (In the video explanation, Fig. 3.3) Why did you draw this curve the way you've drawn it?*
2. **Michael.** *Because the gradient gives you the rate of acceleration, the steeper the gradient the greater the acceleration. It initially left the hand, that was the greatest acceleration. It's the steepest gradient, but then it's slowing down effectively, the ball as it gets near the top of the throw. The rate of acceleration or the gradient is decreasing until just for a fraction of a second I don't know, for an instant at the top of the throw there's no velocity at all.*

He is curving the graph to represent slowing down so he is thinking about position time, even though he started thinking about v/t data.

3. **Interviewer.** *If we look at the graph when it's at the top, you're saying it's at rest.*

We are looking at Fig 3.3. Michael is concerned about the concept of instantaneous rest. I bring him back to the graph data.

4. **Interviewer.** *But look at your graph, is it saying it's at rest?*

Move 4 illustrates an important VSReflection technique. Michael must be "stimulated" into thinking about the data.

5. **Michael.** *No, it has velocity.*
6. **Interviewer.** *Yes.*
7. **Michael.** *Okay.*
8. **Michael.** *That is interesting. Yes. It had lots of velocity.*
9. **Michael.** *I got it completely wrong. I've done a distance-time graph there haven't I?*

Michael has worked out the issue with his explanation. This was a profound step forward for him and this data does not fully reflect the impact this technique has made on him (see 3.4). My reflection in and on action (Schön, 1987, 1995) helped me to develop the coaching session to follow. Finally I asked Michael to summarise the reflection task.

> **Michael.** *I think I described most of the ball's (motion) from the video and then pretty much just drew the graph without, without really explaining what the line on the graph is showing, or really discussing it. I didn't talk really at this point about gradient or what that might mean or any of those things. I just literally said you can see the balls going up and you can see the balls coming down. Then I started drawing*

a line on the graph without really explaining what the line meant. When I watched the video back that was my feeling. T3.2[2]

Michael has reflected on the action(Schön, 1987, 1995) and reached the same conclusions that I have. T3.2[2] He understands what it means to explain something well. He did not think about the variables or use the constant acceleration model as he drew the graph. We now moved to the coaching phase armed with our VSReflection insights.

3.3.2 Coaching

I used the “follow me” (Schön, 1987, 1995) coaching approach. The session took place in Michael’s lab. I demonstrated the action of a motion sensor and he was able to control the apparatus by the end of the session. Michael discussed how he could use the techniques demonstrated, to deliver physics teaching to his year 11. T3.2[3]

I decided to use the motion sensor to produce another v/t and video data from a new motion experiment. I wanted to exemplify the constant acceleration model and demonstrate its use for analysis of v/t graphs.

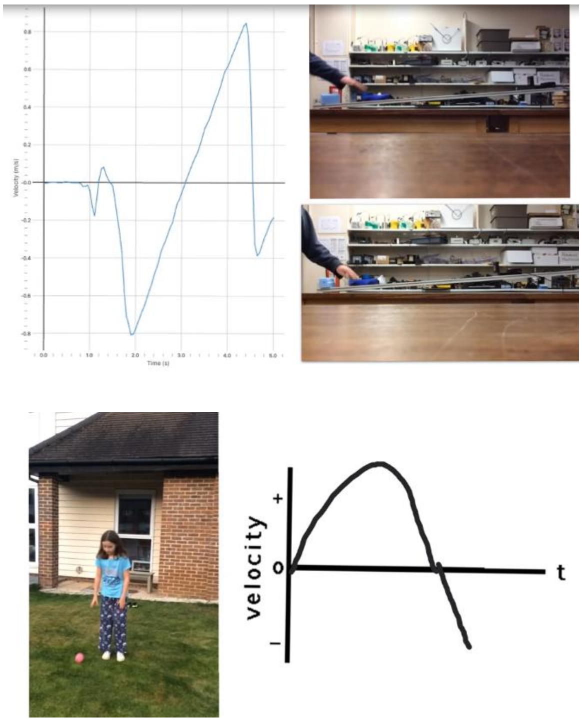


Fig 3.5 Coaching v/t data compared to Michael’s graph.

I compared this new data to one of Michael’s images, Fig 3.5 and we discussed how the graphs were related. The screen casting environment in which I had placed my data, allowed us to use video synchronisation to the v/t graph data. I used the “hall of mirrors” coaching technique(Schön, 1987, 1995) to show Michael how I would teach this material. I had produced a personalised workshop, teaching a physics model, PSMK and simultaneously developed PPCK, the use of data logging and video synchronisation.

Workshop Summary

1. Through use of VSReflection on an explanation, we exposed a weakness in Michael’s grasp of the constant acceleration model.
2. Then, using video and data logging, a simple practical demonstration, I was able to help him think again about the velocity time graph for the ball’s motion. T3.2[3]
3. He then produced a new explanation of the motion. T3.2[2]

3.3.3 Lesson

I decided to write field notes and not video the observed lesson, a mistake I would not make again in this project. Michael had given his class the outline of his first explanation and he wanted them to make and present their own explanation. He was reacting to my “hall of mirrors” (Schön, 1987, 1995) coaching. T3.2[2]. I erroneously concluded there would be little dialogue in the lesson for video to capture.

There were technical issues with getting the pupil explanations to project on the screen. This was tough for Michael to manage, but he succeeded. T3.2[3].

Pupil Group 2 did a good job describing their graph. They did not explain their graph, there was no evidence of use of the constant acceleration model and no logical connections between their statements.

Michael then asked a really good question in an attempt to get pupils thinking, and I could see that he was using ideas from the intensive coaching session. T3.2[2+3] He was working with the constant acceleration model and exploring ideas with the pupils. T3.2[3+4] I had never seen him react in the moment like this with a class. He was in dialogic interactive mode(Mortimer and Scott, 2003) and he had not pre-planned this interaction.

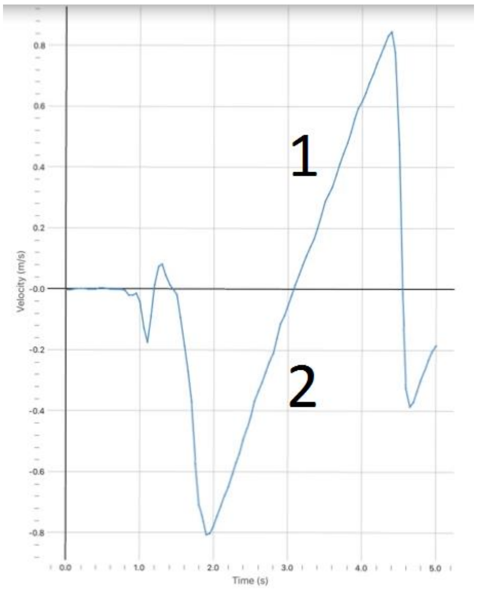


Fig. 3.6 Question

The Group 2 pupils had a graph similar to Fig 3.6. This is an image we had discussed at great length in coaching.

Michael. *Is the gradient of section 1 and 2 the same? T3.2[4+5]*

The group replied no. Michael helped the group to explore his question by using F=ma. It was pleasing to see Michael working with a model and working on ideas with a group. T3.2[3+4] I regretted not having recorded the lesson, and this would not happen again.

In Appendix 3.D there is a full summary of another group's presentation

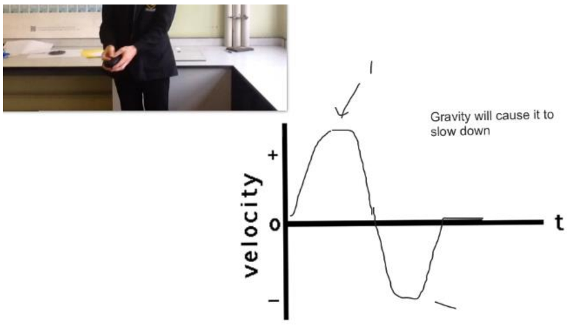


Fig 3.7 Pupils Explain.

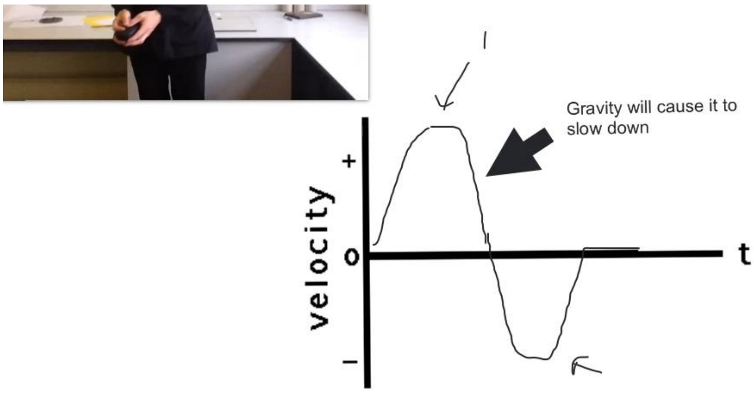


Fig 3.8 Pupils talk more.

In Fig 3.7 Fig 3.8, there are two images from their captured explanation. I inferred from this data that Michael had managed to get over the essential ideas of the constant acceleration model to these pupils. T3.2[2+3+4] They have avoided the misconceptions that plagued Michael's first attempt at this exercise. And although they have not used F=ma explicitly, it has guided their thinking. This data together with the interview data, convinced me that Michael had used the coaching experience. T3.2[3] I could not conclude that Michael had a CIA(Hillier, J, 2013) of this physics. I realised that only a longitudinal study would allow me to verify this and so question M2 was no longer considered explicitly.

After the lesson I conducted an interview, (V)SReflection2. I asked Michael what he had learned about his pupils;

1. **Michael.** *It really showed some of their misconceptions about the graph, I think they-- The tendency is still to try and think about a distance-time graph. So whenever the object is -- I think they mix up shape of the distance-time graph and they've lost the velocity time graph, which I was doing as well. So when they show that line or the gradient of the line going down, their thinking of that as the ball returning to the hand, as opposed to the velocity changing.*

Michel has learned from the VSReflection1 exercise and he now uses this PSMK/PPCK to reflect on his teaching experience in this lesson. T3.2[2] I went on to ask about the effect our coaching session had on the lesson.

2. **Michael.** *Huge amount in the sense -- Well, it helped me. The preparation helped me to tackle my misconception. I think I was making the same mistake initially, I think. Possibly, I did a quite quickly, the video on it. You almost follow the pattern that the ball makes in the air. You must follow that pattern on the graph without really thinking about as velocity. So yes, you almost sketch with your finger that the ball goes up and it goes down. So you sketch that on the graph as well.*

Michael re-affirms my analysis of his initial explanation. T3.2[2]

3. **Michael**. *Lots of students did. It was really interesting because having done that activity with you, I'm looking out for that. I was expecting them to make that mistake almost so you bring it up and you highlight it and you can discuss it.*

He has reflected on the coaching and has developed PPCK. T3.2[2]

4. **Michael**. *It would have almost been worth possibly going back to video I originally shot as well and getting them to discuss that and explain where I had gone wrong and what was wrong with it. They might as well do that as a follow up.*

Michael echoes my thought on why he produced the graph he did for the VSreflection1 exercise. He has learned about his pupils by being my pupil; experiencing physics in the way they do. This was a powerful insight for me.

5. **Interviewer.** *You had that lovely data captured (data-logging used) the beginning of the lesson. But pupils didn't get to talk about the data.*
6. **Michael.** *No. I wanted them to plot the graph themselves because I need them to practice doing that for the exam because things like that will come up. Then I wanted to the follow with them looking at the data on the board and to explain what's happening at each point as the line changes, as the gradient changes and everything. So that's what I will do to next lesson. But it's taking me longer than I would probably spend. I think it's really worthwhile because I think had I just spent one lesson on that, those misconceptions would have gone unchallenged and I would have gone to exam and on into life with those misconceptions. It's great, it's made me really think much more carefully how you teach it.*

Michael was happy to spend time getting ideas right and not worry too much about the lesson plan. This was a very big change in practice for him.

7. **Interviewer.** *You asked a great question about the gradient in portion two (Fig. 3.6) and in portion one. The first pupil speaking said that the gradients would be different and gave you some descriptions as to why that would be case. Then you kept on at them and you helped them think about it asking questions. I think you put up some stuff about F=ma. Then the second boy got the answer, he understood the reasoning.*
8. **Michael.** *He did, yes.*
9. **Interviewer.** *For me, looking at you, that was a real step forward.*
10. **Michael.** *Yes, definitely and I felt it was as well, yes. In the follow up lesson, I'll be really looking for that, when I get them to interpret the graph. I will really focus on that part of the graph. I'm willing to fully explain why the gradient doesn't change. T3.2[5]*

Michael is committing to making sure all the pupils understand the reasoning behind the fact that the gradient of section 1 and 2 Fig 3.6 are the same. T3.2[5]

11. **Interviewer.** *Well, I think you've identified the misconception that most pupils have got and you know how to deal with it.*
12. **Michael.** *Because I had them myself. [laughs]*

I feel after this comment and his reaction, that our coaching relationship is secure. Our collaboration will allow him to confront some big misconceptions without any feeling of insecurity.

13. **Interviewer.** *Could you see yourself using these sorts of recorded explanations recorded for assessment?*
14. **Michael.** *Yes definitely because you could give really good feedback on it. It would be fantastic for revision, later on.*

Even if the physics had not gone well, Michael sees power and potential for learning and assessment, in the screen capture explanation technique. T3.2[2+5]

This completed AR1.

3.3.4 AR1 Summary

Following Justi and van Driel(2005) IMTPG, Interconnected Model of Teacher Professional Growth, Fig 3.9, I produced the following summary of AR1 Fig 3.10, using Table 3.1.

The figure originally presented here cannot be made freely available via ORA because of copyright. The figure was sourced at Justi, R. and van Driel, J. (2005) 'A case study of the development of a beginning chemistry teacher's knowledge about models and modelling', Research in Science Education, 35(2–3), pp. 197–219. doi: 10.1007/s11165-004-7583-z.

A proposed definition list for the links was created early in cycle, Table 3.1

	Definition of Link
1	Michael's **existing** SMK/PCK leads to questions and discussion. VSReflection 1 helps.
2	Michael reflects on tutorial episode and develops PSMK/PPCK.
3	Tutorial experience influences class room behaviour.
4	Michael's **modified** PSMK/PPCK influences class room behaviour.
5	Michael's PSMK/PPCK changes on reflection on practice. Aided by VSR2 and post lesson interview.
6	Reflection on lesson data determines salient outcome.
7	Previous or new outcomes affect teaching. All reflection data important.
8	PSMK/PPCK modified by reflection on outcomes.
9	Deciding after reflection what is salient using PSMK/PPCK.

Table 3.1

The final depiction of Michael's knowledge development following AR1 is summarised in Fig 3.10, Table 3.2, using the coded data highlighted in the previous sections.

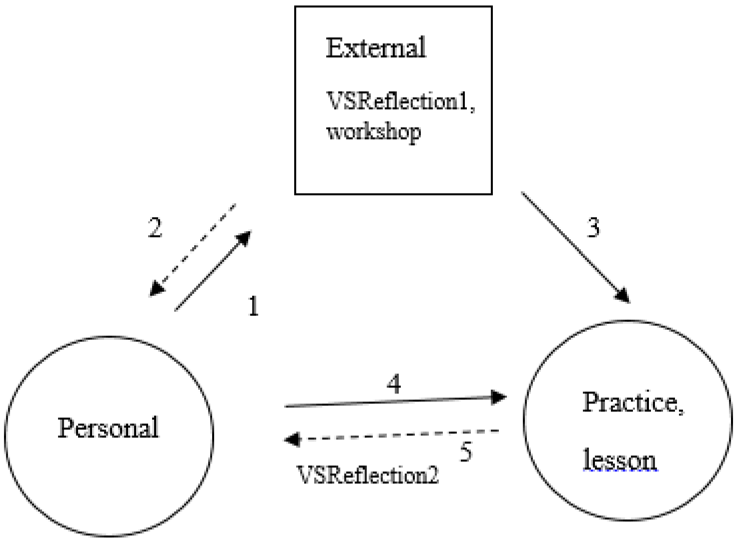


Fig 3.10 Michael after AR1

	Inferences from Data
1	Michael's **existing** SMK has been found wanting. VSReflection1 has lead to Michael voicing questions and discussion of his misconceptions.
2	Michael reflected on tutorial and VSreflection1 as evidenced by excellent questioning episode in lesson. Some pupils had avoided his misconception, so Michael had a better understanding of the constant acceleration model, underpinning his teaching.
3	He used data-logging and the capture explanation technique in his lesson.
4	He was more dialogic during questioning episode about gradients of v/t graph. He was exploring ideas with pupils.
5	In VSReflection2 Michael reflected on what was a new physics teaching experience for him. He understood the pupils' misconceptions because he had the same ones and now he knew how to address them in a classroom situation.

Table 3.2

At this stage using Justi and van Driel(2005) would allow me to make a tentative claim that Michael had developed a growth network, based on the number of links inferred in Fig.3.10.

I would not go so far, preferring an approach that considers longitudinal development in time and physics topic area, before making strong claims about growth development. Also I felt my links definition would evolve over further AR cycles.

Returning to research question (M1). I can from my data and interpretation scheme produce evidence to claim that I have affected Michaels PSMK/PPCK in this intervention. I cannot say anything about his CIA of this physics knowledge domain, without a longitudinal element to the project. Only by "spiralling back" to mechanics later in the year and examining more lesson data can I answer question (M2).

3.3.5 Reflection on Methodology

I produced a summary icon for this TED process Fig. 3.11. DDAME imposed on the IMTPG became an essential design and evaluation tool.

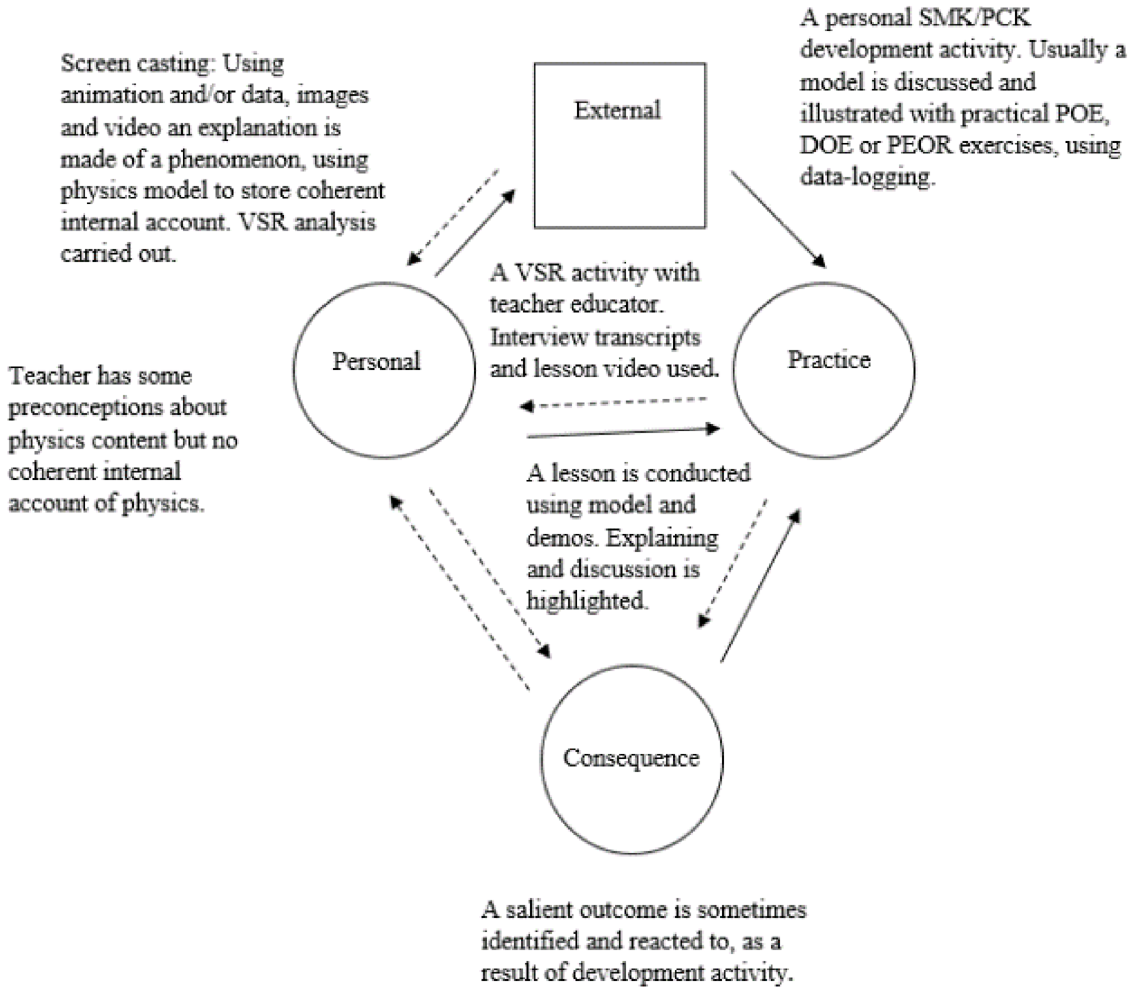


Fig 3.11 DDAME

I was unhappy about how I conducted VSReflection1 at the start of the coaching workshop. I had the explanation data prior to meeting Michael and I had reflected on what it was saying about Michael's PSMK/PPCK. I did not however know what *new issues* the VSRflection1 exercise would reveal. I designed parts of the coaching workshop "in action" and I felt this was unsatisfactory as I might have needed resources not available in Michael's lab. I evolved the AR1 scheme to make VSReflection1 a separate meeting, prior to the coaching meeting, Fig 3.12. Between VSReflection 1 and coaching session there would be time to revisit newly surfaced problems.

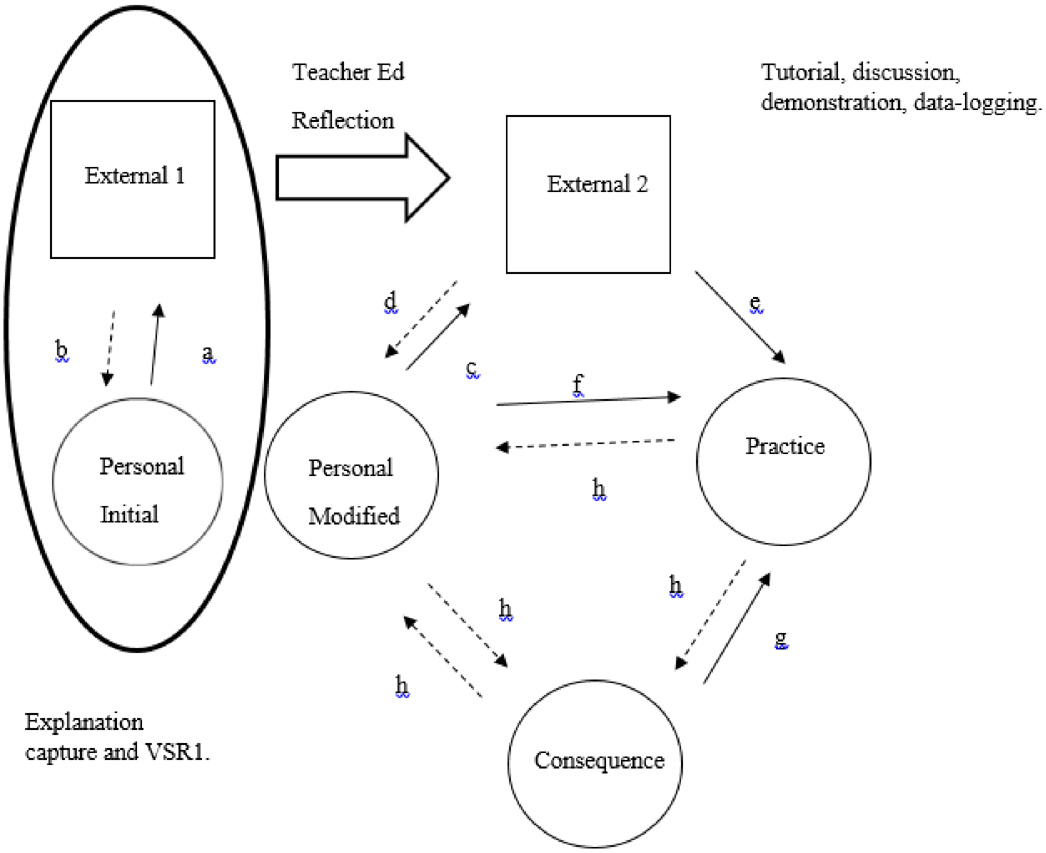


Fig. 3.12. Modified IMTPG Framework

The links, Fig. 3.12, carry a letter to try to convey the temporal development of the process. This must not be taken as a rigid ordering, as the IMTPG was designed precisely to capture the individual learning pathway of each teacher.

3.4 A Surprising Event: AR2

The teaching context for AR2 was radioactive decay. I planned a preliminary talk with Michael to work out what I would ask him to do for VSReflection1. Before I discuss this I want to consider an important dialogue.

Michael was very animated about some AR work he had started. I had noted during AR1 that Michael was excited by the VSReflection1 experience. The technique of multimodal explanation capture had made an impression. We had talked about its potential for assessment and he had acted on these reflections on action (Schön, 1987, 1995), to research his own practice as an expert Biology teacher.

I asked him about his project.

1. **Michael.** *It's a top set year seven, we've been learning about cells in biology. Within that we've been learning about diffusion and we discussed it yesterday. They were struggling to explain diffusion in the lesson. I decided to use the same techniques as we did recently.*
2. *We had a very simple practical, where we used agar jelly with food dye in it. We were placing it in water at different temperatures and then we observed that the dye diffused at different rates in the different temperatures.*
3. *Then I was getting them to explain what was happening.*
4. *It helped me to pick out some misconceptions really quickly. I think the first video we watched, the student had thought or they'd explained, that the red-dye or red dye particles, as they were calling them, were dyeing the water particles. They had this idea that the water was actually changing colour, and it was a really interesting discussion we had from that.*

Moves 2 to 4 show Michael following the DDAME structure. T3.2[2+5]

The power of the explanation capture technique to encourage discussion, expose misconception and facilitate concept change was recognised by Michael.

5. **Interviewer.** *Great and you're going to use this technique to assess their work?*
6. **Michael.** *Yes, that's the idea. Rather than just doing it on paper, yes. I'll use that. We have some success criteria and we'll use a video. I'll feedback to them on that. I can give them written feedback on in the video.*

Michael was keen to develop the method for assessment.

This was encouraging as I now felt he was interested in the DDAME method, starting to apply it in his teaching. Michael was keen to begin another AR cycle in physics. This episode could be used to infer that Michael had salient outcomes from AR1. Elements of DDAME were being adopted and applied by him, to his teaching of Biology. T3.3[6].

I considered the same research question (M1) in this cycle as in AR1. I discussed this radioactive decay AR cycle in assignment 3(Author, 2017b) and so in this section I will only examine critical data.

Using (VS)Reflection, interview transcript data and field notes, I will employ the IMTPG (Fig 3.12, Table 3.1) to address question (M1).

3.4.1 Reflection1

I recorded our preliminary discussion so I could reflect on its content later. I used the transcript as Reflection1 data. Michael leads off the discussion.

1. **Michael.** *I was planning on demonstrating half-life using a data logger and using that to plot a graph. Then I was hoping to do something quite similar to the last sessions,(AR1).*

Michael wanted to set up a lesson with the same structure as the motion lesson. I inferred that he believed the intervention would improve his PSMK/PPCK. T3.3[5+6]

2. **Interviewer.** *I asked about key ideas in this topic*
3. **Michael.** *We've talked about decay before. I think we haven't discussed half-life at all so we need to start really from the first principles. I think because I'm a biologist, I talk to them about carbon 14 and use that as an example. Sometimes I find articles about the carbon dating and get them to discuss from that how it's possible for them to work out ages. Then I'd quite often do some activity where we show that this is random decay.*

I decided to focus the coaching session on randomness.

4. **Interviewer.** *Let's talk about a random activity, how might you discuss that?*

I was thinking about radioactivity, Becquerels, Michael was thinking about "teaching activity". This problem will be discussed at length in the following analysis. Unfortunately I did not pick up on this issue until the VSReflection2 post teaching exercise.

5. **Michael.** *I've done it before where you just get some popcorn and stick it on a pan with a Bunsen burner and you just have 20 popcorn notes or whatever they're called and then you can try and predict which one is going to be next, which one's going to pop next.*
6. **Michael.** *It's the fact that you can work out a half-life from it because you can time how long it-- or you can video it maybe. I've done this and maybe next time I could do this for explaining*
7. **Interviewer.** *If you think about the number of corn kernels that have popped in a given amount of time at the beginning compared to the end, what do you notice there?*

I am still thinking about the activity concept.

8. **Michael.** *I'm not sure what you're asking.*

Michael does not see what I am getting at.

9. **Interviewer.** *If you're listening to it, it's going pop, pop, pop, what do you notice about the rate of popping as time goes on?*
10. **Michael.** *Initially there's a much higher rate and the rate of popping falls away. There's another one as well which you could do. We can get a mic, rather than*

doing that you can actually do this one, use the sounds of the pop rather than counting the kernels

But then he says what I want to hear in line 10. But crucially he never uses the word activity to describe this phenomenon. T3.3[1]

11. **Interviewer.** *Yes, but there's another way that sometimes it's done. You've got 24 pupils in here, you could give them all a dice and then get them to sit down or stand up when they throw a six.*
12. **Michael.** *I've done that before as well.*
13. **Interviewer.** *It's a good activity.*

I am using activity in Michael's sense now.

The above analysis was not my original analysis of the data. The original analysis informed the coaching session as described in the next section. This current analysis was made for this work, following consideration of VSReflection2 data. At the end of AR2 I realised that reconsidering reflection data was a technique that should be a part of the methodology. This re-analysis of VSReflection data has become important in subsequent work.

I showed Michael how to use a Geiger Muller, GM, data-logger with the software we had used in AR1. Michael seemed confident in this area of physics. T3.3[1]

At the end of this discussion I had no idea what to set as the explanation task for VSReflection1. There were school pressures on Michael to teach the material, so fitting in the preliminary reflection phase (Fig 3.13) that I hoped would expose misconceptions, would be impossible. I decided to proceed without this initial phase of the intervention.

3.4.2 Coaching and Lesson

When I arrived for the coaching session there were more surprises!

(1) Following our earlier discussion Michael had decided to demonstrate the GM data logger to his department. Technical issues had spoilt his demo so we "experimented together"(Schön, 1987, 1995) to resolve the problem. This established a new dimension in our coaching relationship and strengthened our AR collaboration.
(2) Michael was talking about sharing our AR1 work with the local IoP teachers group. T3.3[5+6].

Michael now *wanted* to use the DDAME framework. I began by showing him how to use the GM data-logger with a Protactinium source that he had. I was developing his PPCK knowledge. He planned to use this experiment in front of a class, a real challenge for a non-specialist.

I produced the following "coaching agenda", models I had to teach him, from consideration of Reflection1 data.

(a) The random nature of decay using computer and dice models of nuclear decay. The computer models in excel were new to Michael.

(b) Random counting error and its affect on decay curves. The activity curves are never smooth, why is that? We collected and discussed decay data.
(c) Using fast data logging to “see” random counting events.

I used the Protactinium demonstration to produce a POE (White, R., and Gunstone, R., 1992:44) for Michael. Using “hall of mirrors”(Schön, 1987, 1995) I wanted to encourage discussion between us about randomness and mother/daughter relationships in nuclear decay chains, the sort of discussion he could then have with pupils.

In my field notes for this session I recorded that Michael seemed confident with this material. T3.2[1]

Michael’s final lesson plan contained the following activities;

(a) Dice model for decay. This involved the whole class, with Michael recording data on the whiteboard. Once again he asked good questions and made few errors. A nice touch was that he varied the probability of decay (1/6 to 1/3) and related results to shape of graph and half-life. Michael used IRE patterns of communication (Mortimer and Scott 2003) but the interaction engaged the pupils and they were thinking about randomness. This was not simple interactive/authoritative communication. T3.3[3+4]
(b) Data-logger activity. Michael produced a Protactinium decay curve as a demo. He wanted to relate the bumpy curve to curves in activity (a). T3.3[2]
(c) Class activity. Using explanation capture software the pupils had to connect activities (a, b). T3.3[2]

3.4.3 Post Lesson Interview

The post lesson interview data affirmed that Michael believed in the AR intervention process and that he felt his PSMK/PPCK was improving.

1. **Interviewer.** *We talked about that lesson in some detail. How do you think it went?*
2. **Michael.** *Yes. It's frustrating because we had some technical issues. They understood why there was going to be, potentially, a lot of variation because of randomness. Everyone I asked really seemed to get that*

Michael asked good questions and handled the technical issues well. From this I inferred that his PSMK/PPCK was developing. T3.3[4]

3. **Interviewer.** *With the explanation activity, what did you really want them to get out of that then?*
4. **Michael.** *I wanted them to be able to look at the graph of the half-life from the data we collected with data logger and the protactinium generator. To explain what it means really.*

Michael wanted clear explanations captured by the pupils. He now sees explanation making as an important activity. T3.3[3+6]

5. **Interviewer.** *Did you pick up any misconceptions in the room as you were going through the ideas?*
6. **Michael.** *Trying to think. Nothing springs to mind. I was, actually, surprised that, as I say, they seem to have quite a good understanding of probability already. I'd have to look back at the video and see if I missed something off.*

He knows he can reflect on the captured video data and indeed I will ask him to do so in VSReflection2. I asked about the dice activity which I had liked.

7. **Michael.** *I've done that activity before and I just made it up myself. I think a lot of teachers do something similar.*
8. **Interviewer.** *I quite like the idea you managed 30 pupils, one die per pupil and actually produced the results on the board. You might have had a go at, because you were talking about half-life, looking at number of rolls to reach half the pupils left.*

In the interview I am starting to use the "see it my way"(Schön, 1987, 1995) coaching technique. Michael has impressively handled the data and dealt with randomness. But he is puzzled by my statement. T3.3[1]

9. **Michael.** *Yes?*
10. **Interviewer.** ***(Using whiteboard)****30 pupils to 15, you can see its just about four rolls needed, and that's exactly what you'd expect.*

I am using the data on the whiteboard from the lesson to carry on coaching Michael.

11. **Michael.** *I might take a photo of that.*

Michael has acquired some PPCK to be used in the future. T3.3[2]

12. **Interviewer.** *You really did well with the "bumpiness" issue, because that was the thing that was bothering you in coaching session.*

I was pleased seeing this episode in the lesson, because we had spent time on the curve's bumpiness in the coaching session. The coaching intervention had made an impression, causing him to reflect on PSMK. T3.3[2]

13. **Interviewer.** *Is there anything you could have done with that first activity, perhaps re-designing it slightly, so that you could have targeted the bumpiness right at the beginning?*
14. **Michael.** *Yes. Just the fact that it's not clear, it's almost a shame it fitted the line so well, isn't it?*

Michael had not understood my point. The curve plotted will always be smooth because it's not activity. This is the first indication that there is a PSMK issue to work on together. This is considered further in VSReflection2 using data from the lesson video.

15. **Interviewer.** *What you could have done is, think about what I'm saying here, what you could of done is repeated the first throw over and over again.*
16. **Michael.** *Okay. That's a good idea. Yes. That's what you were showing with the Excel spreadsheet in coaching, is that right?*

Another interesting passage. Michael has not grasped the idea until I elaborate, line15, where I am using the activity concept. He then connects his thinking to our coaching discussion using the computer model. T3.3[2]

There is lots of dialogue I have edited out. I resume analysis at the point where we are talking about how half-life relates to amount of nuclei present.

17. **Interviewer.** *You said, "What about a 100 rather than a 1,000. Would you expect faster decay? Someone said, "Faster".*
18. **Michael.** *Decay faster, yes, exactly. Now, that's a misconception. But then one of the other students immediately challenged it. Did you hear pupil 1 immediately say, "No it wouldn't because the problem presented is exactly the same." Meaning the decay probability is the same. Maybe I should have made more of that.*
19. **Michael.** *That whole idea, that's the misconception, isn't it? With fewer dice, they're going to decay quicker somehow. Yes. Okay.*

I have used field notes to guide Michael to consideration of an important misconception I had picked up observing the lesson. He understands the issue. He is also thinking about PPCK, he could indeed have made more of this dialogue. T3.3[5+6]

I ask him to consider AR2 and to pick out what influenced his work in class.

20. **Michael.** *Well I possibly wouldn't have done the demonstration with the protactinium generator because we wouldn't have had the data logger.*

PPCK influenced again in coaching. Michael makes some remarks about his usual teaching style, saying;

> *I would have started off with the dice activity. Basically, collect the data and then get them to plot the graph. Then we'd have discussed those graphs probably just done some questions. Got an exam question and gone straight to that.*

Then he talks about our intervention.

> *Whereas I feel with this, you pick up the misconception much more. I do feel this allows you to, as you say, really tackle their understanding. Whereas a lot of the time you just settle on, "Can they answer the exam questions well enough to get some marks? Yes. Let's move on to the next topic." Whereas this I really feel like you're challenging them to think hard about what's happening.*

This is an important passage. It affirms again Michael's belief in DDAME. He is aware of where he was as a physics teacher and after expressing the desire to change. Michael feels he is progressing. T3.3[5+6]

> *As a teacher, it really allows you to get a better understanding of their comprehension of the topic. Also, it's made me think really hard about it as well.*

Michael is experiencing physics learning from the pupils' perspective and it is helping him. Again this reframing of problems(Schön, 1987, 1995) is an important experience. T3.3[6]

21. **Michael.** *The process has really challenged me because, as I say, We wouldn't have used the protactinium generator. I wouldn't have discussed that random, the*

bumpiness at all. Well, I was confused when we did it, the first time. I was confused why it was going all over the place. I thought there was something wrong with it. So it just shows.[laughter] T3.3[5+6]

3.4.4 VSReflection2

I had extensive video data of the lesson to consider. I prepared a script to help me with the VSReflection process, Appendix 3.F.

I identified episodes by repeatedly watching the lesson video and thinking about the Reflection1 data. I produced 4 episodes: Activity, Half-life Emily, John half- life and 1 in 11. I was guided in the video editing process by my reflections from coaching and Reflection1. There are other possible episodes and this is an important point, referring back to the issue concerning how we interpret data in AR to produce evidence. I was happy with my selection given the post lesson interview data. I was interested in the data in Activity episode, because it revealed coaching work I needed to do with Michael. This is VSReflection2 that I will now discuss. We are interacting with the video as this interview is conducted.

1. **Interviewer.** *We're at a stage in the lesson where you're comparing data from the data logger (Activity data) with your dice simulation (Number of pupils left in dice simulation). Thinking back now to those two graphs. I'm going to use the word Activity. Which graph shows an Activity?*
2. **Michael.** *Well, by Activity, do we mean something that's changing? I'd of thought. Sorry, go on.*

My suspicion is confirmed, Activity is a concept Michael is not happy using. It is not part of his CIA for nuclear physics.

3. **Interviewer.** *Activity, is disintegrations per second.*
4. **Michael.** *I suppose they both are. This, you're measuring the radiation, the one with the decay, you're measuring the radiation that's being produced per second by the decay. The other one, well, you're seeing, effectively, people being lost from the game, or-*

He is not clear on what is being plotted and clearly was not thinking about this during the lesson. I had not picked up on this until looking at the lesson video data. My new analysis of our preliminary conversation points to the corn popping narrative, where I thought Michael was happy with Activity, this was a “critical incident” in our coaching session that I had missed completely.

5. **Interviewer.** *What did we plot though? In the simulation.*
6. **Michael.** *The number of people who were still in the game, who hadn't been eliminated?*
7. **Interviewer.** *Okay.*
8. **Michael.** *Yes. Effectively, they were the people that hadn't broken down.*
9. **Interviewer.** *Is that an activity?*
10. **Michael.** *No, I suppose that's the opposite. That's the people who are inactive. Whereas, this is the active, yes.*

“See it my way”(Schön, 1987, 1995) coaching is guiding my actions but I am not happy with the outcome yet. I am not sure Michael has grasped the idea despite reflecting on this passage with me.

11. **Interviewer.** *All right? That's a very important point because, in the whole sequence that I've shown you, you didn't use the word activity once.*
12. **Michael.** *No, I didn't, no. It's all about radioactivity, yes. [laughs] That makes sense.*

I had not realised that he had not used such an important word until analysing the video data.

13. **Interviewer.** *I'll tell you why activity would be good to use. If you want to get at this bumpiness idea. If you had all 30 dice and you repeat the one throw, counting the sixes, you're measuring, effectively, the activity after one throw. You can see the variation in the activity.*
14. **Michael.** *Okay. Get it, yes. That makes sense. It never occurred to me to think about, from that point of view, yes. That, again, is something I'd need to discuss in future. Yes.*

I relate this back to our previous discussion about randomness and activity. He is seeing how this concept can be used to discuss data we have considered. I have now developed an important aspect of his PSMK. T3.3[5]

In Appendix 3.G I include the data for the 100 versus 1000 nuclei discussion. Again I infer from analysis of the data that he has developed an important aspect of his PSMK

3.4.5 Summary

Again the research question can be answered confidently. Michael has developed PSMK/PPCK after this intervention.

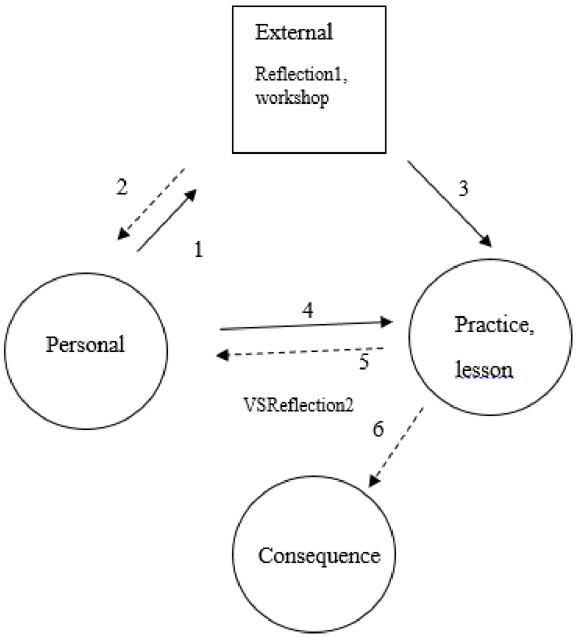


Fig. 3.13 IMTPG AR2

	Inferences from Data
1	In coaching Michael had ideas about randomness.
2	He plans to use Protactinium source and data-logging. He reflects on bumpiness of activity curve. DDAME is in mind from AR1.
3	He tries to model lesson structure on AR1 lesson. Content is largely derived from coaching.
4	He carries out interactive/dialogic activity on dice model. He demonstrates and captures activity data.
5	He reflects on meaning of Activity and how it can be used in the classroom to improve the activities he used.
6	He is convinced of the value of making explanations, examining them and using data to stimulate explanation making.

Table 3.3

I found in this cycle further affirmation that Michael believes in the effectiveness of this AR intervention and that his knowledge domains are being changed.

I am happy with the revised methodology from AR1. I would have picked up the “Activity” misconception issue with a suitable VSReflection1. Of course time constraints and my failure to spot the potential problem in my preliminary discussion with Michael had led to me not using a VSReflection1 activity.

I note also from this AR cycle the power of re-analysing Reflection data after completion of the cycle. Such analysis can help me to improve my own practice as a TED.

3.5 Electromagnetic Induction AR3

Again I was unsure what exercise to use for VSReflection1. Electromagnetism is a tricky topic to teach, even for a specialist, so I decided to reverse the order of coaching and VSReflction1, Fig3.12. I planned during VSReflection1, to make alterations on screen to Michaels' presentation as well as recording the usual interview data. This would give him further ideas to reflect on after we had completed VSReflection1. Live annotation, became a new coaching technique.

3.5.1 Coaching 1

I introduced the Faraday flux rule, using experimental POE(White and Gunstone, 1992) puzzles, plus the "Faraday Lab"(University of Colarado, 2017). We worked on the concepts of Flux density and rate of change of Flux (linked) as a key model to explain the demonstrations. This model was introduced when it became apparent that Michael's attempts at explaining the demonstrations were confused. He used energy and wave models inappropriately to try to make explanations in response to my questions. T3.4[1]. I had identified a gap in his PSMK knowledge. I asked Michael to produce his own "captured explanation" of the demonstrations, using the flux model. I encouraged him to use PhET animations and the data from experiments in the coaching session, for this meaning making exercise. This provided the data for VSReflection1. T3.4[1+3]

Magnetic field and voltage sensors were used to collect data to inform our discussion of the flux rule. I had provided some practical apparatus and I used this as we worked on the ideas. I was using the "see it my way" coaching approach(Schön, 1987, 1995), to develop Michael's PPCK for this unit. The detailed coaching content is contained in Appendix 3.H. This coaching session was difficult because Michael was learning to use a new and abstract concept. T3.3[2]

3.5.2 VSReflection1 and Coaching 2

Michael used data-logging to produce captured explanation data for the VSRefelction1 exercise. T3.4[3]

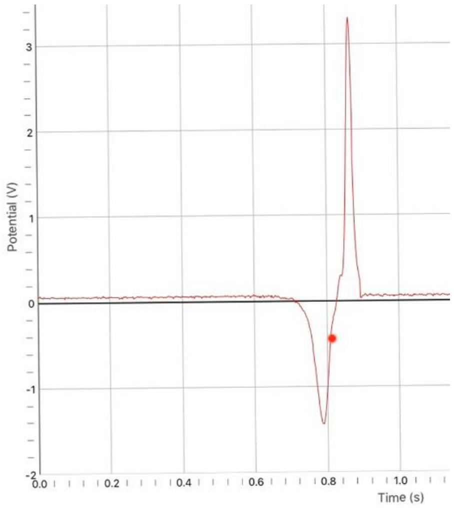


Fig. 3.14 Induced voltage data

Michael produced Fig. 3.14 for his explanation. He said;

> *"Magnetic field lines interact with the electrons, pushing the electrons making a current."*

Michael used a "field lines pushing" model rather than the flux rule.

> *"The field lines going in the opposite direction create the positive potential difference."*

He is happy that the magnets acceleration can be used to understand the difference in the magnitude of the voltages and elements of the flux rule are present in his commentary. T3.4[3]

> *"its moving more quickly (magnet) so more energy can be given to the electrons, so more voltage."*

Again he chooses not to use the flux rule that his pupils used this energy model in the lesson.

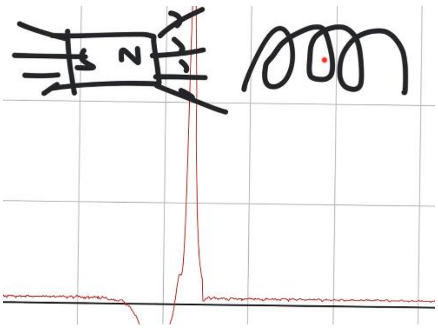


Fig. 3.15 Working on VSReflection1.

Michael's original VSReflection1 was 6 minutes long. We worked on it together, Fig 3.15, talking and annotating for 20 more minutes. This was a "follow me" with touches of "hall of mirrors" coaching episode(Schön, 1987, 1995). In effect VSReflection 1 was moving smoothly into Coaching2. Working in this way is an effective coaching technique.

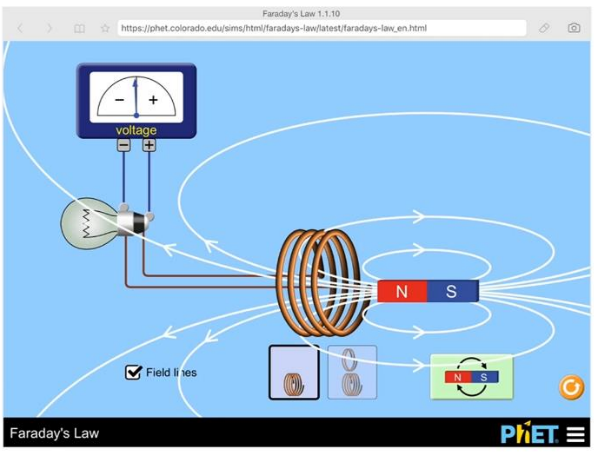


Fig 3.16 Experimenting together with a web browser in the explanation capture software.

Michael discovered that web browsers can be used inside the capture software. He worked on the flux rule using this facility. Manipulating the animation and adding explanatory commentary. He subsequently used this technique in the lessons as did his pupils. T3.4[1+2+3]

3.5.3 The Lesson: Shaking Torch

In his teaching lab Michael had set up demonstrations from our coaching 1 session, including the falling magnet experiment.

Michael asked the class to explain why the shaking torch produced flashes of light. Michael used dialogic/authoritative communication (Mortimer and Scott 2003). A pupil said,

> *"inducing a current in the coil"*

Michael asked for detail. Another pupil refered vaguely to

> *"interaction between electrons and field",*

Michael evaluated this as on the right track.

Michael was using the script from coaching 1 session. T3.4[3] I inferred that the coaching methods employed resulted in change to his personal knowledge domain.(Clark and Hollingsworth, 2002).

Michael made the falling magnet demonstration using the data logger. T3.4[3] There were technical hitches but he persevered until data was captured. (He was more confident when demonstrations failed.) Field notes data provided evidence to support the claim that he is developed PPCK. T3.4[2] He produced data (Fig 3.14) as we did in coaching1 and he engaged the class in talk about the data. T3.4[2+6]

Michael then used the PhET simulation(University of Colarado, 2017) that we worked on in VSReflection1 annotation Fig. 3.15, to help him discuss the flux rule. Michael substituted use of the flux rule for his spurious energy explanations seen early on in coaching1. T3.4[1+2] A pupil used the "field lines pushing charges" model in an answer and this was ignored by Michael. So despite using the flux rule Michael was not always aware when pupils used more intuitive models.

Michael projected his explanation discussed in VSReflection1 for the class to watch. He stopped the presentation to discuss with the class the question about the difference in voltage size between the peaks and a pupil offered the answer about gravity pulling the magnet down and so it was falling quicker. He worked with this pupil to discuss the fact that the exiting pole was moving faster. This is behaviour I modelled with Michael in coaching. T3.4[1+2]

Michael told the class about how hard he found the task of producing an explanation for the falling magnet experiment. He then showed them how to use a web browser in the explanation capture software, steering them towards using the flux rule. This is an interesting episode because Michael models explanation making in front of his class, mirroring the technique I and he used in coaching. T3.4[6]. He wants them to consider the shaking torch as an example of induction that needs explaining.

Michael wanted his pupils to present their explanations, but technical issues again precluded this. A pupil was asked to present without technology and did this, using the flux rule. This was the longest I have heard a pupil talking physics in Michael's lesson. Michael asked questions during the presentation, using the pupils' captured explanation to help frame questions. This was not his usual IRE pattern of dialogue. He worked on ideas with pupils and used the captured explanation to stimulate and support discussion. T4.3[6+7]

Another pupil made a presentation about the shaking torch. Magnetic flux lines pushing against the electrons was the preferred model with this pupil. Michael asked for comments on voltage peak sign and size from the class. Fig. 3.14.

> *"Can you try to explain the graph? Why did you draw the graph that you did?"*

This is an open question requiring more thought from the pupils. T3.4[3+7]

Another pupil uses gravity giving energy to magnet to explain voltage a model Michael too has used. Michael persists why negative then positive voltage?

> *"One end (magnet) is + one end –,"*

said a pupil.

> *"But its not."*

said Michael, magnets have north and south, not charged ends. This was good dialogue, Michael was not closing down the discussion. He was keen to get the class explaining and using their recorded explanations gave him ideas to work on with them. The lesson ended with a problem concerning Lenz's law. T3.4[7].

3.5.4 Post Lesson Interview: VSReflection2

In this session I was reflecting with Michael on the lesson. I used the lesson apparatus to capture data for use probing his understanding of the flux rule. I used the video of the lesson to stimulate reflection.

1. **Interviewer.** *All right, we're looking at the apparatus that you used in one of your demos today. It's the clear plastic tube and the coil. You measured the voltage induced in the coil, as you drop a magnet down the tube. What I'd like you to do is tell me the difference, you'd expect in the voltage-time graph, if you had the coil here at the bottom where you had it in class, and if you had it at the top of the tube, where you drop the magnet?*
2. **Michael.** *The peaks would be -- wouldn't they be smaller peaks?*
3. **Interviewer.** *Where?*
4. **Michael.** *At the top, it's not moving quickly, the magnet, so therefore the field lines won't be moving through the coil as quickly, so you'll get less potential difference.*

This is a good answer based on the flux rule. It's not perfect because he is not using rate of change of flux, but this is something we can build on. T3.4[2+3]

5. **Michael.** *Also, they'll be further apart because it takes longer for the magnet to actually pass through the coil at the top than it does at the bottom.*
6. **Interviewer.** *Right, so the time interval?*
7. **Michael.** *The time interval, yes.*

Michael goes further. He thinks about accelerating magnets and the implication for the application of the flux rule. This is a very important piece of data. He is starting to integrate models. It is a sign, but for me not strong enough evidence yet, to claim development of a growth network. T3.4[2+4]

8. **Interviewer.** *What about the size of the first peak compared to the second peak in each of those positions?*
9. **Michael.** *It would still be a smaller peak, so there'd be two peaks there.*
10. ***I*****nterviewer.** *At the top?*
11. **Michael.** *Yes, versus the two peaks at the bottom. In both cases, the first peak would be smaller than the second peak, whether it was at the top or the bottom, but both peaks would be smaller than the peaks down here, I'd have thought.*
12. **Interviewer.** *Why would you think that?*
13. **Michael.** *Because, again, it's moving more slowly so the field lines are changing. As they pass through the coil, they're changing more slowly. The density is changing more slowly.*

Michael sticks to his reasoning based on his understanding of motion and the flux rule. I am using “see it my way”(Schön, 1987, 1995)to explore the last question. This is also “hall of mirrors”(Schön, 1987, 1995) because the way I am working with Michael now, is how I want Michael to work with his class. We talk about what to expect in the graph shapes if the magnet reaches terminal velocity, this is good progress in developing PSMK T3.4[2+3], (Appendix 3.J).

There is a lot more data on various demonstrations that I did at the end of the session, but I will consider one more episode on Lenz’s law which connected to the next lesson Michael planned to teach. I asked him how he intended to deal with Lenz’s law.

1. **Michael.** *I’m going to read about it before. [laughs] I’m going to make sure I have got a better understanding of it, because at the minute I think my understanding again is quite limited. So we have -- I mean, basing on the Flemings rule my understanding is that the direction of the current pole is going to be a right-angles to the magnetic field. So, as the magnet drops through the magnetic field swaps direction. It’s going to push the current in the opposite direction.*

Despite a detailed intervention in VSReflection 1, coaching 2 (Fig 3.15), the flux rule was not yet part of a coherent account of this physics for Michael.

2. **Interviewer.** *That doesn’t sound convincing does it?*
3. **Michael.** *I’m not convinced about that at all.*
4. **Interviewer.** *Okay, now can you try now to make the explanation but this time in your reasoning use the demonstration where we had the dynamo -- and I shorted the output of the dynamo as you were turning it, so there was a big current flowing. You suddenly found it hard to turn the dynamo!*

This demo was made in coaching 2 and the effect really surprised Michael. He used it in VSReflection3. T3.4[3]

5. **Michael.** *So then when you do that you get a current in the wire that then generates a magnetic field that pushes back against the magnet in the dynamo.*

6. **Interviewer.** *So compare the north-south going in, explain why they must be opposite.*

Michael gets the idea. I am not convinced he recalled and was using Fig 3.15 above.

7. **Michael.** *They must be opposite, they repel each other they stop each other-*
8. **Interviewer.** *So as the north is going in what are you saying about the electromagnet that you are making? What are you saying about the pole of the electromagnet?*
9. **Michael.** *It must be the opposite, it must be in the south-pole for electro magnet you are making.*
10. **Interviewer.** *That wouldn't be repelling then, if you got a north magnet falling into the coil and you're saying that the electromagnetic becomes a south pole then they are attracting.*
11. **Michael.** *So it's the opposite then yes.*
12. **Interviewer.** *So when the magnet comes in and its north, you're saying that the coil, the electromagnet facing it is a north. What about when it leaves then? So we have got the south leaving-*
13. **Michael:** *Yes, so then it should repel it.*
14. **Interviewer:** *You need to draw, maybe draw a picture.*

We recreate fig 3.15 above. This dialogue continues for 10 more moves. Appendix 3.K. This interaction gives a flavour of coaching and how it evolves during periods of reflection.

3.5.5 VSReflection 3

I wanted Michael to make another explanation of Lenz's law so we could reflect on the new data. He produced VSReflection3, an added reflection phase.

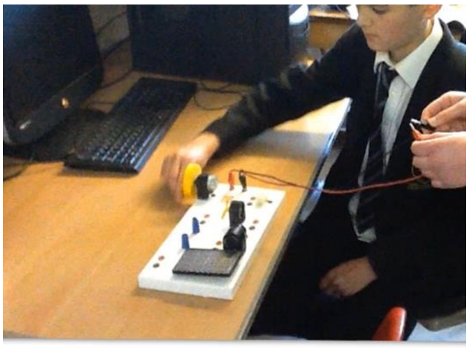


Fig 3.17 Odd Behaviour

Michael's new explanation consisted of a video of the shorting dynamo output experiment Fig 3.17. This was effective as the pupil suddenly stopped turning the crank shaft (they could not help this) when the other pupil touched the contacts together. T3.4[3+4]

1. **Interviewer.** *I've been looking at your explanation. Tell me very briefly why you chose the first slide.*
2. **Michael.** *I just think it's quite an interesting phenomena. You showed it to me for the first time the other week. I couldn't have explained it myself why that happened initially. To be honest, I'm still trying to. I felt that if we could explain that well, then it would illustrate Lenz's Law quite well.*

This episode in coaching made a big impression on Michael. He knew it was important to be able to explain this phenomenon. T3.4[1+2+3]

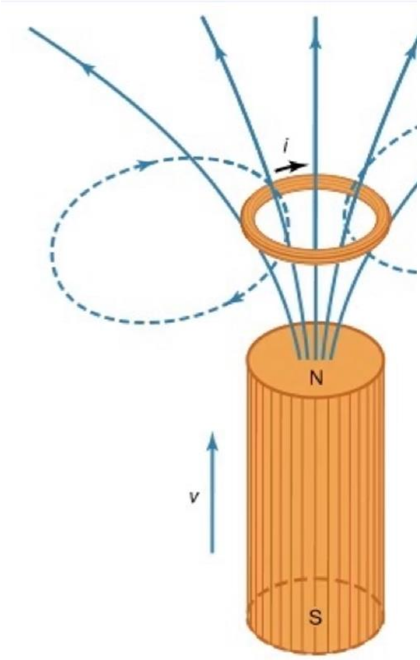


Fig 3.18 Physics Book

Michael used an image, Fig 3.18, from a physics text, but not convincingly. I invited him to discuss this image.

1. **Michael:** *My understanding of Lenz's Law is effectively that if you induce a current in a wire, then you're going to get a magnetic field that effectively oppose it. When you push them, a few inches of current with the magnet, you have to move the magnet towards or past the current. The magnetic field, that it will oppose the-- Quite confused. I did this last week. I just cleared my head last week and now I've actually-- I've bubbled again.*

Michael cannot use this picture. He is confused. This is not a problem for us. A state of confusion means we can reflect and start to build understanding.

2. **Interviewer:** *Lenz's Law is tricky. If we now look at the picture, the lower portion shows a bar magnet moving up towards a coil of wire.*

I get him started in thinking about the image, but do not give too much away.

3. **Michael:** *We can see the field lines of flux. It's going to change, which is going to induce because they're changing as they move through the coil. That's going to induce the current. Then the direction of the current, as the current moves around obviously, that's going to generate because that's have going to have a magnetic field. That's going to oppose the movement of the magnet it goes through.*

A more coherent response, but we are not finished. We talk more about the diagram.

4. **Michael.** *Well, they're the flux lines from the bar magnet, they're pushing through the loop.*
5. **Interviewer.** *Good.*
6. **Michael.** *These are the field lines. This is the magnetic field around the coil due to the current.*
7. **Interviewer.** *Correct.*
8. **Michael.** *Then they're opposing each other?*
9. **Interviewer.** *Right.*

He is looking at the field line directions.

10. **Michael:** *As you move forward, the two magnetic fields will oppose. Then as you move it back because you're changing the direction of the current by opposing the other direction as well.*

This dialogue goes on for some time. We consider carefully Fig. 3.18. I end the discussion before Michael gets frustrated, but progress is made. T3.4[2]. Appendix 3.L contains the last phase of our reflection on Lenz's law and again illustrates the style of coaching we are developing.

3.5.6 Summary

At the end of this last AR cycle we have the following methodology summary Fig 3.20.

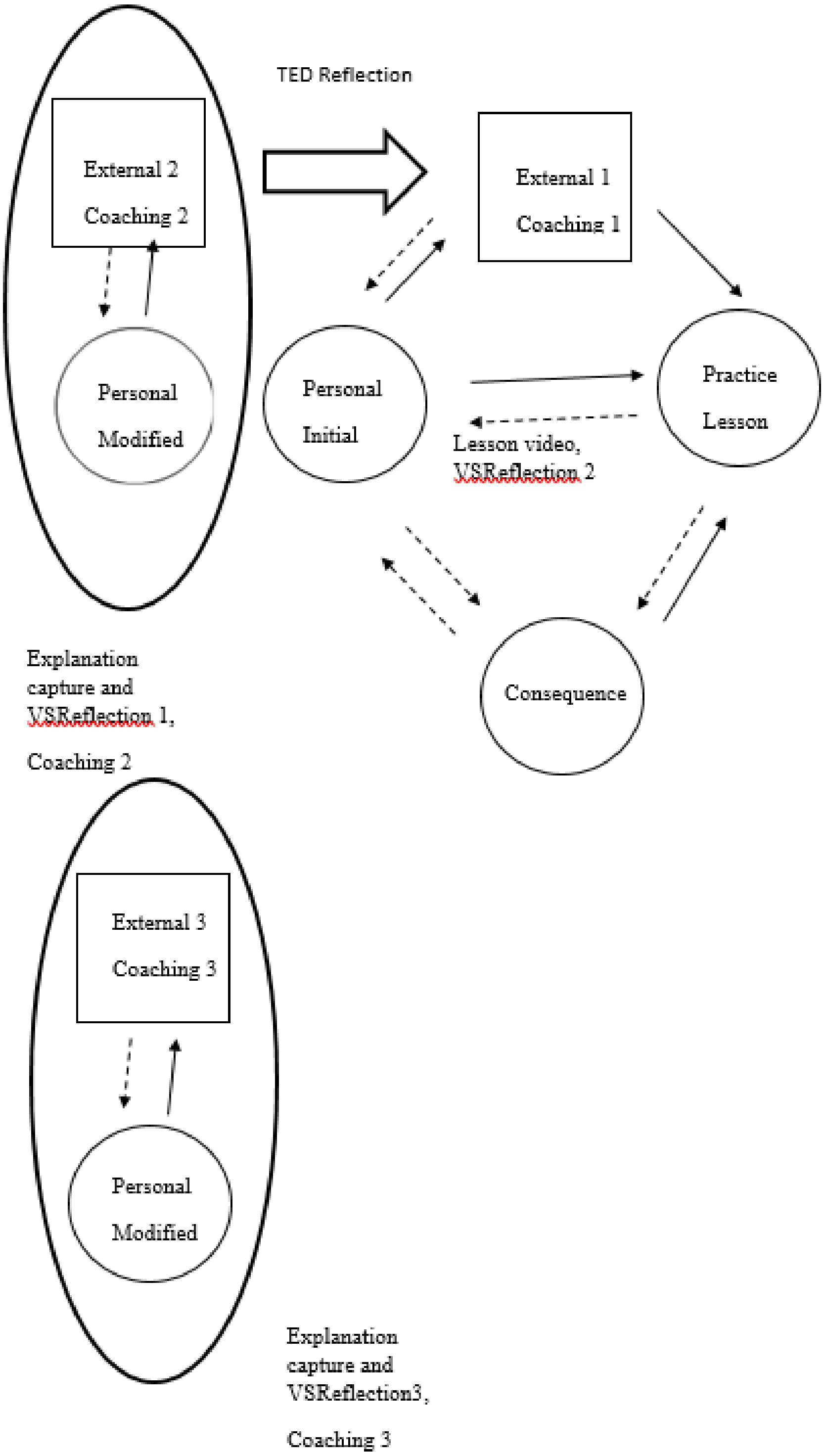


Fig 3.20 IMTPG Final

Coaching session orders have been flipped and further VSReflection sessions have been added.

Again I can confidently answer the research question concerning Michaels' PSMK/PPCK. I will summarise my conclusions with the usual IMTPG icon developed from the data analysed.

	Inferences from Data
1	In all the coaching phases of the intervention, Michael is using his PSMK to interact with me.
2	Michael certainly develops PPCK after coaching 1 and 2, using the explanation software and data logging in lessons. He has reflected on the VSReflection tasks and although not totally successful, he has made progress with PSMK on flux rule.
3	He uses the script/theory and practical skills learned, from our coaching 1 session in his lesson.
4	He is very affected by the explanation capture software and wants the pupils to use it. Pupils are talking for more of the class time than I have ever seen.
6	Michael used the explanation capture technique to help his working on ideas with pupils.
7	Michael is allowing to pupils to speak for longer and he is asking more exploratory questions. He believes in using data and making explanations and is willing to use these techniques in his teaching.

Table 3.4

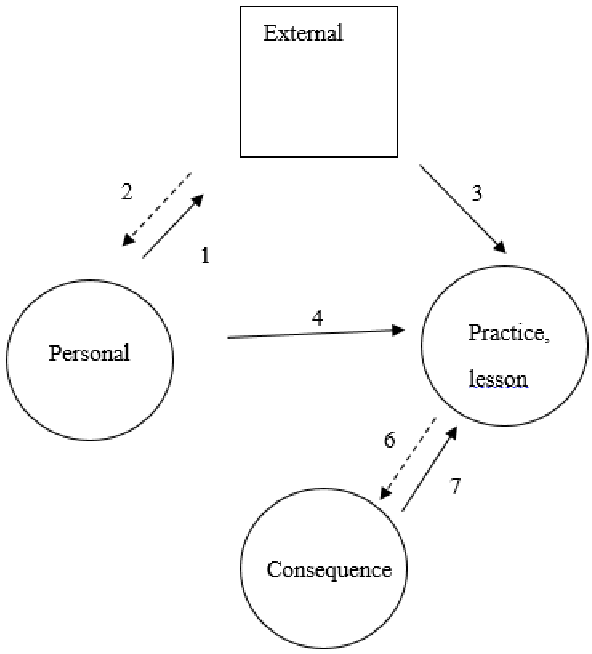


Fig 3.21 IMTPG AR3

3.5.7 Michael Terminal Interview

The full transcript is contained in Appendix 3.M. This is extremely important data and runs to 1000 words of testimony.

I ask Michael about the DDAME Experience.

> *From my own personal point of view I found it incredibly helpful in that as I've been through the process with you, it has—using explanation capture, particularly, has really picked out my misconceptions and the mistakes I was making.*
>
> *I found that it certainly really improved my practice and really improved my understanding of physics, generally, as a topic*
>
> *I've liked the fact that it's made me think-- before I started teaching, it actually made me think deeply about the topic. .*
>
> *I think the problem with any of these topics is that you don't actually know what you don't know, if that makes sense.*

I believe that Michael feels he has learned a useful way to improve his PSMK/PPCK. He realises how important it is to confront misconceptions and this can be done via reflection with a coach.

I ask about “good” Physics teaching.

> *to really get the idea across, you need to be able to explain it really clearly and really well. That requires really good subject knowledge. Otherwise it ends up being a very superficial explanation and then you just gloss over the bits that you're not clear on.*

Michael understands what it means to explain something well and how important it is to develop PSMK as a non-specialist. Otherwise you transmit ideas and remain non-interactive and authoritative. (Mortimer and Scott 2002)

Going Forward

I ask about techniques learned and how they could be used.

> *I've already tried to use the same techniques with different groups as well. I'm not just teaching physics. I generally use it to change my practice and I've used it with all sorts of different ability groups and all sorts of different ages.*

Michael is already using the explanation capture in his own AR.

What have we been doing?

> *I would say that it's a tool that you can use as a teacher to get-- If you use it before the lesson, it allows you to really-- by trying to explain what you are teaching-- the concept, it really makes you think more deeply about what's happening. There are two sides to it. I think as a teacher it really allows you to recognize misconceptions that you have and it allows you to really work through them to a certain extent, especially if you've got support.*
>
> *Again I still would like to look at it, extending the idea, so you can use it to give them more feedback, but I think that, again, that's something for their future and there's also technical issues that seem to be holding on for the minute.*

Michael has summarised this AR project beautifully in his own words. Returning to the research question again at the end of this episode we have made changes to his knowledge domains. More importantly Michael is believing in the efficacy of this coaching practicum.

4 Coaching Conference: Peer Review

I presented aspects of my AR work, particularly explanation capture and analysis, at the Institute of Physics, IoP, Supporting Physics Teachers, SPT coaches' conference. Three 45 minute workshops were conducted appendix 4.A. I received encouraging feedback on the explanation capture technique.

33 delegates (all very experienced physics teachers, mentors and coaches) filled in a questionnaire Appendix 4.B. 11 delegates expressed interest in collaborating on the development of VSReflection going forward. Table 4.1 contains a summary of some of the questionnaire data.

Some comments express similar views to those put forward by Michael in his last interview. Delegates 2, 4 and 29 allude to issues concerned with the security of the coaching relationship. 5, 17, 21 and 29 declare the advantage listening to explanation aspect of the capture technique.

	Would you consider using the technique, "explanation capture, VSR"? If so what did you like about it? What problems do you see with using it?
2	I would consider using it but more for coaching/mentoring rather than in the classroom. It was a great tool for allowing teachers to reflect on their practice in a non-threatening way. It allowed for some very useful "aha" events.
4	Yes if the nature of the relationship with the mentee and the time available for mentoring lends itself to the process. I can see it being very valuable indeed.
5	I would consider it in the right circumstances. See Q2. To use a cliché, "what's not to like?" about the process. An excellent and effective insight into the current knowledge and understanding of an area and its development through exploration. I am thinking of use with students as I'm not in a mentoring situation.
17	Yes-especially for hearing the explanations thinking through process. The idea it does not need to be completed at a set time and can be sent remotely. Problems-Technology lack of
21	Possibly with students and coaching. Good points-independent, not led by coach-given a chance for free flow of ideas and insight into the chain of thought. Problems-time consuming, based on availability of software and hardware.
29	To promote individuals own learning. Allowing me to set tasks (coaching and mentoring tasks) that then gives someone the time and opportunity to construct a solution. I particularly like the fact that images and voice can be captured as a video file and then reviewed. Accessing some ones thinking is used appropriately would be valuable to watch learning happen. A problem might be that it becomes over critical; think the respondent may be too concerned with being right or wrong and so will overly plan a response.

Table 4.1 Questionnaire Data.

There was confusion about the purpose of the technique, coaching with pupils or teachers, and the cost implications if data logging is made an integral part. Inevitably some delegates saw technical and cost issues, 17, 21, 23. The fact that working in this way is very time consuming, 23, was viewed as a major drawback. However 11 delegates would like to work on developing the VSReflection technique further.

5. Conclusion

5.1 Roger and Nicola

AR with Roger and Nicola helped with the development of coaching ideas and the clarification of what dialogic/interactive (Mortimer and Scott, 2003) physics teaching looks like.

Working with Roger allowed me to identify and start to understand, the problem of "cognitive noise". Going forward in this project, I need to consider how pupils cope in a highly interactive episode, do they feel the tension that exists between dialogic and authoritative pedagogy, (Scott, Mortimer and Aguiar, 2006).

Working with Nicola allowed me to develop the use of the explanation capture software and to start refining VSReflection, as a primary coaching technique in a reflective practicum, (Mackinnon, 1989) The use of this technique as a coaching tool needs refining so that I can create a workshop, to teach its use to those IoP practitioners who expressed an interest in its use. Appendix 4.B.

5.2 Michael

Looking back at the baseline data, 3.2, an important development is taking place; Michael now makes time and is happy, to work on ideas with pupils. With the frameworks of Clarke and Hollingsworth (2002) and Mortimer and Scott (2003) in mind, I revisited Tables 3.1, 3.2, 3.3, 3.4, to produce Table 5.1 as a summary.

	Link discussion, IMTPG (Clark and Hollingsworth, 2002)
1	Michael had plenty to say in coaching workshops. VSReflection techniques helped with this, even though they often exposed his misconceptions. He was committed to making a change in his practice and he very quickly felt the DDAME technique was helping. Our coaching relationship allowed him to feel secure about not knowing and this an essential factor in the success of this intervention.
2	PSMK/PPCK was developed as a result of reflective practice during coaching. Making explanations, thinking allowed, using models and data were important activities for him.
3	The coaching workshop was often a "hall of mirrors" and "follow me" experience (Schön, 1987, 1995). Michael acquired the confidence to do technical demonstrations and to discuss data without the rigid lesson guide often employed. He used the workshop to build a lesson for pupils.
4	Michael asked questions requiring more than a response, they were informed by a new appreciation of pupil misconceptions and difficulty with abstract ideas, because he had had those very same experiences. He moved beyond IREIRE dialogue, (Mortimer and Scott, 2003).
5	Michael's PSMK/PPCK changed aided by additional reflection phases. Lesson and interview data stimulated this and coaching became integrated with reflection.
6	Michael started to use the explanation capture technique is lessons. He wants to develop its use for assessment and pupil support. He is not intimidated by technical issues that plagued him when using the technique with pupils.
7	On reflection he wanted to sue DDAME in his teaching.
8/9	I found this hard to quantify in the project. I am sure Michael's personal knowledge domain was profoundly influenced by the explanation capture technique, because he wanted to use it in teaching and experiment with it on his own for assessment. I did not collect data which allowed me to produce evidence to support the existence of links 8 and 9.

Table 5.1 Intervention Outcomes.

The final interview data, 3.5.6 and Appendix 3.K, provide compelling evidence to support the claim that Michael's PSMK/PPCK has been developed by this intervention, in answer to my first research question. I abandoned consideration of research question 2, because early on in the project I concluded that a longitudinal study would be needed to answer it. I am keen to explore knowledge growth (Clark and Hollingsworth, 2002; Justi and van Driel, 2006) and development of CIA (Hillier, 2013), with Michael going forward next year.

5.3 Validity

I now consider the validity of my claims. Returning to Whitehead (1989) and McNiff (2016:18), I can without doubt affirm that a critical and enquiring approach was employed using cycles of study that evolved from AR1 to AR3. I have presented data to justify my claim that Michael's PSMK/PPCK has been changed. The IoP coaching conference data provides evidence in addition to that provided from Michael's study, to justify the claim that the VSReflection technique could be effective as part of a reflective coaching practicum. I presented data to the coaches at the IoP conference and discussed how I was using the VSReflection technique to develop PSMK/PPCK. Their comments and feedback were positive. I am keen to work with 11 of these coaches who expressed an interest in this work, to develop the technique, providing new data to inform and develop VSReflection using explanation capture software. I personally believe that DDAME including VSReflction, will be useful in my work as a TED. I also have started to use VSReflection in assessment mode with pupils, following Michael's lead.

5.4 The Future

My ultimate objective is for Michael to be able to take his teaching of physics forward without my specific and personal, interventions. Evaluation of his CIA of physics and growth network development, are important research projects for next year.

A non-specialist colleague of Michael's has expressed interest in an AR project following DDAME techniques. This will facilitate further refinement of the AR methodology in this project. In the next phase of work, I want to start considering pupil data. Can the pupils see a difference in teaching and learning as a result of their teacher trying these techniques? I am keen to answer this question.

I want to investigate the effect on pupil learning of "cognitive noise", in highly dialogic/interactive teaching. Roger and I will work collaboratively, to explore the dialogic authoritative "tension", using Scott, Mortimer and Aguiar (2006).

While I was working with my autumn/spring SKE students, this project was significantly influencing my practice. Three ITT students, Dan, Estelle and Lililan formed a work group. I thought they were close friends, but that turned out not to be the case. They felt comfortable in the coaching environment because of the way I was approaching the task.

Estelle had a PhD in physics, Dan was an engineer and Lilian a physics non-specialist. This grouping is usually not encouraged in SKE work. Diverse knowledge backgrounds are seen as problematical.

I used Schön's ideas on coaching(1987, 2016) with this group. The concept of the reflective practicum(Mackinnon, 1989) was becoming clearer and was influencing my work. Key elements of reflective coaching are;

(a) Developing a professional and secure relationship. Student confidence, making sure they feel able to interact without feeling reserved/anxious about assessment or judgement.
(b) Encouraging the student to surface ideas as you do, modelling reflection in and on action.

Post course interview data (Appendix 5.A full interview transcript) showed that I had encouraged reflective behaviour in a supportive environment. Importantly I had built a successful coaching relationship with these students very quickly.

When asked about the SKE course Lilian commented;

> *…it was more about what I felt or we made it about getting rid your own misconceptions, making sure you truly understood…. It was more about, "Do you understand?" I needed a forum to be able to work on that, for myself.*
>
> *You have to be willing to put yourself out there and fail, but I'd rather fail here than out in the classroom and that fixes your mind, doesn't it?*

Lilian was comfortable surfacing problems and she realised how important it was to do so.

> *There was flexibility in what we were discussing on a weekly basis. The needs of the group, you would flex completely to how quickly we were catching on or whether we needed more time on the ideas.*

I had to reflect in action to address the needs of the group. (Appendix 1.A)

Estelle echoed Lilian feelings about the security of the coaching environment.

> *Yes, it was absolutely fine to fail here because everyone makes comments that were wrong or they had misconceptions and therefore it was totally safe. In this room, you can talk complete nonsense and its fine.*

Estelle highlighted the PPCK/PSMK approach using DDAME

> *Here was very much a mix of science and pedagogy. It wasn't just, "This isn't..We're having a physics class." We weren't having a physics class, we were having a teaching physics class, which is different.*

When asked about use of techniques modelled Estelle commented about POE;

> ***Interviewer:*** *Is that something that's part of your teaching repertoire?*
>
> ***Estelle:*** *Yes, I keep doing the predict, observe, explain.*

The project has thus achieved the principal goal of AR, to stimulate change in professional practice.

5.5 What have I been doing?

The last words should be Michael's;

> *…..by trying to explain what you are teaching-- the concept, it really makes you think more deeply about what's happening. …..I think as a teacher it (reflective practicum) really allows you to recognize misconceptions that you have and it allows you to really work through them to a certain extent, especially if you've got support.*

On the 15th June 2018, I received an email from Michael that confirmed my positive feelings about DDAME. (Appendix 5B). He wrote,

> *here's the first question from the physics paper. It's exactly what we did with year 11 in the lessons you helped me with. We made EE videos to explain this very graph! Hopefully they remembered it!!*

I have tangible results from this research. I believe many coaches and physics teachers will find the DDAME/IMTPG technique useful.

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Appendix 1.A

Notes from my work with non-specialist physics teachers who attend sessions in autumn through to March. (Lilian, Estelle and Dan; Final interview transcript, Appendix 5.A)

Yesterday I was conducting a subject knowledge booster session, with 5 teacher training students that I have been working with since October. I want to discuss something that happened in that session, which illustrates perfectly how my courses will develop.

I was doing a refraction demo with slinky springs, one that I always do. As I conducted the activity, I became "unconvinced" by the demo. The teacher back-talk was convincing me that this was not working as a an experience to illustrate refraction. Usually I would plough on through, taking the teachers with me, we do this as teachers of pupils all the time, because they often do not back-talk when we are in authoritative teaching mode. I shared my "reflection in action" with the teachers.

I was keen to make the demo compelling, because of the way I teach refraction. So I modelled, using Schon "see it my way" coaching technique, how I would make the demo more compelling, using a plastic and steel slinky. The process took longer and they saw it happening in front of their eyes. I was totally honest about my experimentation in practice to improve learning. I was questioning a demo, I had become convinced worked really well. I was using PSMK to improve learning for the teachers and so developing PPCK for me and hopefully them. They saw my professional artistry.

I felt I understood what Schon was saying on reflecting on this episode. His debate about technical rationality versus professional artistry has significance, as the wealth of literature discussing his work testifies. Developing teacher practice rooted in educational theory, a technical rational epistemology, is only part of what I should be doing as a teacher educator. The harder task is to coach teachers to be active, reflective-researchers in their classrooms. This is the way to develop CH growth networks. Schon provides the key ideas on coaching and always being conscious of our practice, critical, looking to question and learn from reframing the data we collect as we teach.

So the developments I am making, converge on the ideas of reflective practice, which includes experimentation in action and designing sessions so enaction and reflection are encouraged and recognised, using CH. Ultimately I want the teachers to grow as professionals, not just know and understand more physics. This is a big change for me.

Appendix 2.A

Motion Lesson

This is a lesson that we talked about at length. I asked Roger to teach me before he did the lesson and I had shared my ideas about DDAME before he met with his class. I did not insist that he teach the class using DDAME methods, but I knew he would teach this in a similar way to me. Roger was my key collaborator in the action research aspect of this project.

There are several really interesting episodes in this lesson. The film was divided into the following episodes by me.

(a) Acceleration is tricky
(b) Fatal flaw
(c) Force diagram
(d) Helping to make an explanation
(e) No thrust needed
(f) We just have weight

In doing this, I just concentrated on what I found to be interesting physics discussion as a classroom physics teacher. I have chosen two episodes to consider at length because they are typical of the dialogic approach employed throughout the lesson.

The lesson style is responsive, interactive with pupil interaction being encouraged and their contributions used to develop understanding of data. The issue is that the demonstration to produce data was left to the end of the lesson when time was running out and the demo was hard to do. Roger had watched me doing the demo with a teacher education class and it looked deceptively simple!

20:10 Making an Explanation 1:19

This episode occurs in the middle of the sequence concerned with explaining the motion of the apple using the model of constant acceleration. Roger has been in interactive dialogue mode for some time. He has established that the only force on the ball is weight.

He asks is the weight constant down, a pupils says no and Roger asks him to explain why. The pupil begins a long explanation dialogue. So we see initially an (I) move and Roger expects an (R) so he can make a high lighting (E) move and move on. He is briefly in authoritative mode to secure consensus over what he believes is a simple point. The wrong answer (Rerror) leads to (Iexplain) from Roger then a long (Rpupil) move with reasoned steps.

The pupil frames their discussion using GPE and Roger does not intervene. This is taking the lesson away from the script, but Roger waits while the pupil thinks aloud. The pupil uses mgh and talks about each variable. When he says mass is a constant, Roger emphasises this statement. When the pupil finishes with g Roger says, "so m an g are constant" again putting key ideas in front of the class. The pupil concludes so as the height increases GPE increases. Roger says "what was my question?"

We have seen;
(I)(Rerror)(Iexplain)(Rexplain)(Rsummary)(Rexplain)(Rsummary)(I)(Rreflection,correction)(E).

The class are voicing their opinions, Roger asks them to let him finish. The pupil making the long dialogue reflects and concludes, mg is constant so weight is constant. He has thought things through. Roger exclaims, “you are right the GPE changes, but the weight is constant.”

This is a particularly rich dialogue, which is not simple IRE, or IRFRFRF. In this 1:19 episode the pupil is talking for 50 seconds or so.

In my field notes for this lesson I recorded to final thoughts.

(1) Discussion creates lots of “cognitive noise”. Is this an issue?
(2) Pupils not involved in the discussion lose concentration. This is an issue!

We have a pupil thinking and talking but his argument is does not answer the question. Roger allows this to flow. Some of the class know he is not answering the question. They want to stop the discussion and are frustrated.

In the post lesson interview I picked up on this issue.

Interviewer: Now, what I really loved, is there was lots of discussion going on. You were dealing with lots of different questions and different ideas. Did you feel that some of the ideas that were being thrown at you were taking you away off course and ruining the flow?

Interviewee: Yes, a little bit. But we know it often happens. Its' a balancing act between dealing with those satisfactorily….

Interviewer: As a very experienced teacher, how do you control that to avoid, what I'm calling, the “cognitive noise”?

Interviewee: One of the difficulties it poses is that, with me leading the discussion, everyone has ideas they want to get out and test and I can't really deal with all of them. It might be a situation where getting people together pairs or small groups to discuss, set them two minutes to discuss their ideas and respond. Because that will often filter out errors. Someone will say something and then someone shouts out. You saw it in that lesson, they correct each other. You give them that chance to test ideas out, to correct each other. We'll then have a feedback, a few minutes, and then you'll get ideas of better quality.

Roger has already reflected on the situation and has some ideas to deal with the questions I have identified. These matter to me because this action research is designed to help me evaluate and improve my own approach to teaching physics which is being modelled by Roger.

20:50 to 24:43 Acceleration is Tricky

Roger summarises that “Force (resultant) is constant and mass id constant so what does that mean for acceleration?” Roger is using F=ma on the white board.

Pupil answers, “Acceleration decreases it won’t go on for ever..” He adds “it won’t accelerate for ever, it has to stop, because the weight goes down..right?”

Roger wants to deal with this interaction. He says, “in what direction is the acceleration?” the pupil responds, “upwards”.

“Ok it is certainly moving upwards at first” says Roger. The adds, “But what would happen to the speed if the acceleration was upwards?” this gets the response he wants.

Then others add in unison “it accelerates a bit though”. Roger emphasises it has left my hand though. There is only one force, the weight down on the ball, he keeps emphasising this.

Roger sees there is confusion. “We are going to have a closed eyes question.” He wants to see what the state of misapprehension is in the room. He asks, “In which direction is the acceleration?” Despite his arguments and summaries the pupils are still going with intuition laded with misconception, it is an exciting battle. He emphasises his plan of attack.

(a) F=ma
(b) There is only one force downwards,
(c) So what can we conclude about a?

This schema should help the pupils answer the question. Results two for up, 15 for down, 6 no commitment.

Then new pupil asks, “what do you mean by accelerates down?” Pupils turn around and interact saying, “decelerates.” The issue is with the vector nature of acceleration and do we use deceleration or accelerates down. Another pupil says “I think it decelerates up.” And then a pupil says “isn’t acceleration a vector quantity, so it goes in the direction its moving in?” We have the core of the misconception revealed.

Roger feels he has to emphasise with an authoritative answer, “the acceleration is down, most people were right.”

He has the issue in focus now, the backtalk has allowed him to understand why he cannot get the dialogue to flow according to his three step plan.

A negative acceleration can be considered a deceleration and he writes a= v-u/t on the white board, to help him reason. Roger now wants to move on and so he refers to three step schema again.

Concluding acceleration is constant. Then pupil says, “it does not seem that it should be”. “That is why this example is so great exclaims Roger.”

Roger says you have motion upwards and downwards but the acceleration is fixed downwards. This of course is the issue that Michael had and I addressed by rolling a cart on an inclined plane using a motion sensor to capture the data. At this stage in the lesson this would be an opportunity to use the data-logger to make a similar move for these year 11 students.

This episode has occupied 5 mins of lesson time and the class has been busy. A minority have an issue and probably many others do not understand the acceleration story as well as Roger wants. The point about DDAME lesson is that he would have an activity now that brings data into consideration. It wold also allow him to do further experiments in reaction to back talk from the students, as he did in the spinning magnet episode from the magnetism lesson. I think our discussion about this lesson may have caused Roger to reflect on how demos and data can help move explanation forward, when thoughtful approaches using physics models are struggling. Interestingly Roger always likes to approach the teaching in his own way, which is why he was an excellent collaborator for my personal action research project on using data from data loggers to facilitate group meaning making.

In the post lesson interview I broached the lack of data issue.

Interviewer: The demonstration was right at the end and was going to produce the data which kids could relate back to what they were discussing and, because of the discussion, time ran out. How would you arrange things if you going to do that again? Would you ever be encouraged to put the data first, for example?

Interviewee: Yes. I can see how you could make that work. You wouldn't need to show the graphics necessarily, you could split it up. You could, actually, do the motion with the data logger. You have the data there already, then you could choose whether to show them at the beginning or not.

This is Roger thinking about POE approach or maybe DOE.

Interviewer: Actually doing the demo was difficult?

Interviewee: Was quite difficult. Obviously, I might have used the video tracker. But if I'd practiced a little bit more.

Interviewer: Practicing was the key thing.

Interviewee: Yes.

Video tracking can produce impressive results for quick analysis. Using the motion sensor live in class requires careful practice.

In this episode there was little cognitive noise. The class were getting tired as was Roger who was keen to get to a consideration of the data that would of course justify the care he had put into making the explanation with the class. The class would see that the story they had created accounted for the data produced by experiment. The class would also see just how much thought had to go into accounting for the data.

Appendix 2.B

Spinning Magnet: 1 minute 51 seconds of intense interactivity. Roger

One student asks about the magnet spinning in the wider coil. He argues that there is more room for magnet to spin in wider tube.

Roger says; "you have to be careful to drop it horizontally,"

Then the pupil persists with a further question about what affect would spinning the magnet have of the V/t graph shape? At the moment the pupils have seen and been discussing/explaining the +-, two peak graph.

Roger pauses and then says, let's try it. It is possible to do the demonstration on the fly because of the data-logging and projection system Before he does the experiment he makes remarks to link the phenomenon to the previous classroom discussion;

"clearly we don't just have a south pole facing down".

He did not plan this action so he is going off plan here. This is a clue to indicate responsive teaching. We can also infer that he is reflecting in action. He is also treating questions and comments with consideration and care. There is no closing down interaction to keep to lesson plans.

While this is happening another pupil adds,

"Could it be its falling faster because the shape of the coil, (large rectangular cross-section compared to diameter of cylindrical magnet,) is not circular like the magnet?" I think this is an argument based predominantly on air drag ideas. Roger cannot analyse this response in detail as he is multitasking.

Roger has the reflection about spinning magnet and he has to handle this question about magnet speed'

Another pupil offers advice about how to set up the experiment,

"why don't you use a clamp?".

Roger has a lot of backtalk to manage.

He answers the question about shape in authoritative mode, then makes an argument involving the relative sizes of the resistance of the wire and tube. He is explaining why the current in the tube will be larger, he makes an error. This is him making sense using eddy currents and lenzs law of the different magnet speeds in tube and coil.

The pupil who wants him to clamp the coil interjects again, but Roger continues with the new demonstration. He ignores the plea to clamp the coil.

He shows the data live. Expressing some anxiety about how well the magnet has spun, he says the data is interesting.

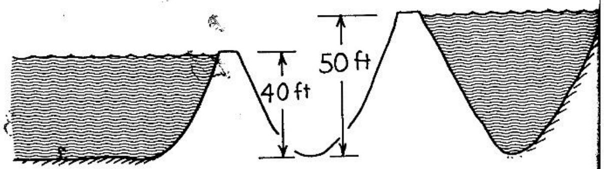
“its not just one spike followed by another”

He explains that he expects to see evidence for magnet rotation to be reflected in the features of the voltage time graph, we should see oscillation. “Several peaks one followed by another.”

Appendix 2.C

Roger Pressure in liquids

BIG DAM LITTLE DAM



Dams are constructed thicker at the bottom than at the top because water pressure against the dam increases with depth. But how about the volume of water held back by a dam?

The Sierra Light and Power Company in California has a dam fifty feet high with a little lake behind it. Not far away the Department of Reclamation also has a dam — only forty feet high, but with a much larger lake behind it. Which dam must be strongest?

a) The Sierra Light and Power dam must be strongest
b) The Department of Reclamation dam must be strongest
c) Both must have the same strength

Video Narrative	Analysis
Roger talks about the question above. *He points out that the 50 foot deep lake is a small volume of water compared to the 40 foot deep lake.*	
1. Roger concludes the preamble saying, "which of the dams has to be stronger?" "And I would quite like a reason if you're going to tell me the answer."	(IRP) We have I from Roger, now R from pupil 1, but it has no physics content.
2. Pupil 1 "I think the 50 foot one will have to be stronger."	Roger prompts for further thought

3. Roger asks, "why?" 4. Pupil 1 "Because it's higher, and it means…. I had a reason, I have forgotten it. But basically because it's higher than the other one it means that there's more…" 5. Roger summarises, "okay so it's higher…(Other pupils start interjecting)… Let him finish" 6. Pupil 1 continues "it has more gravitational potential… 7. Another pupil adds quietly, addressing pupil 1 "there's more pressure"… 8. Roger praises pupil 1 for his attempt at an answer: "you are making an effort" Roger picks up on this comment and discusses how the concept of gravitational potential relates to the water in the lake. 9. He adds, "although we have not studied gravitational potential energy and you won't till next year, there is some bearing on the situation there." 10. Pupil 2 offers an answer. "I think B because usually shorter things are kind of sturdier and they don't..{inaudible}" 11. Roger summarises," okay so you think the shorter dam, which has a wider amount of water in it, okay so" 12. Roger invites the class to "close your eyes." He is employing a technique to get the class	Pupil 1 is given time to respond and Roger protects his thinking time as well as offering summary of what has been said so far. This is F response not a direct E. But notice as happens in many open dialogue episodes in a classroom, pupils start to offer "help", by giving the answer. **Roger is developing an atmosphere where dialogue is encouraged and supported. This is an essential facet of his approach to teaching physics**. Pupil 1 energy approach to the answer is not dismissed by Roger. He brings in some physics reasoning to show how this approach could be relevant. So we have had an IRF cycle and no answer yet but a F(d) phase has been introduced. This is an intuitive pupil response not guided by physics discussed so far. This is a classic "misconception" response, R(m) (new nomenclature for this analysis, R(m) response revealing misconception in evidence). **Roger now acknowledges internally that the class has no clear consensus on the**

to answer the question honestly, putting up their hands, without seeing the answers being offered by their peers.	**right answer. He needs to show the class what the range of thinking is**.
13. Roger summarises the results: “so roughly 5 in favour of the tall one, seven in favour of this short one and one in favour of the same.”	
14. Roger asks the class, “Turn to the person next you and see if they agree or disagree with your answer.”	**Again in keeping with his beliefs on teaching and learning Roger initiates a period of discourse between neighbours**.
One pupil gives the correct answer in terms of pressure being related to the depth of water, as Roger wanders around the class observing the groups discussing this problem.	**The class is engaging in productive dialogue.**
15. Lots of pupils are now talking about pressure, “I agree with you pupil 1 it’s about more pressure,” pupil 3 exclaims.	**This is an I move but guided by careful discussion. I will call this an I(d) move. (A question is initiated but potential answer scaffolded by teacher discussion.)**
16. Roger takes command, “there is still a lot of disagreement.” **17.** He offers some advice about how to analyse this problem. **“In this situation I always try to think…. Well… Let’s think about 1 foot tall dam, 1000 km wide... compared to this 50 foot damn… Which needs to be stronger?**	R move. F move. The discourse is moving the way Roger wants now.
18. Pupil 4, “the 50 foot one,” 19. Roger summarises, “does everyone agree the 50 foot one?”	**Part of the F move, evolving into F(d).** The question has engaged this class. **But it turns out this is not the end of this IRF dialogue**.
He draws a diagram summarising the above argument. Pupils are discussing the ideas as Roger draws on the board.	R(m) move based on P=F/A. This is another opportunity to deal with the key misconception that amount of water, volume, mass etc is important when answering this question.
Pupil 5 offers an inaudible analysis based on P=F/A, arguing that the area of the 1 foot	Roger is thinking how to manage the next discourse.

dam wall is so much bigger compared to the 50 foot dam wall that the pressure exerted by the weight of water should be less.	F(d), obvious nomenclature, Roger feeds back but with extensive discussion.
20. “Interesting” Roger comments.	R move.
Roger has to design the problem so that the walls have the same area to try to counteract this new argument. Again he draws good diagrams on the whiteboard.	
21. Pupil 6 takes up the area theme and tries to carry on with an analysis. “If you have more area for the same amount of water, behind the 40 foot dam the pressure of water has more space to spread out..”	I move. **There is no F or E move by Roger, the class and he are in deep discussion**. R move.
22. Roger asks, “which area are we talking about?”	R move by same boy continues.
23. Pupil 6, “basically everything.”	
Pupil 6 continues to argue the case for the 40 foot dam. I think he’s arguing about bigger volume of water.	**This has been a multiphase IRF…dialogue and has taken 10 minutes of lesson time.** F(c) (feedback to close dialogue) move.
24. Roger becomes more authoritative. “In fact it’s to do with, because I don’t want to spend too long on this, continue to think about this question as we proceed, and a lot of you have said this already, the key issue is the h in this equation, P=h.d.g,” Roger points to the equation on the whiteboard.	F(c) move continues in some detail.
25. He continues with his authoritative dialogue, “the pressure in a liquid, does depend on density, but we can assume that constant, certainly for 50 foot of water, g we can assume is constant, so it really only depends on depth.”	
26. “So in fact this problem is simpler than it seems.”	
27. “So at the bottom of the 50 foot dam	

it will be experiencing a bigger pressure."	

By move 13 Roger knows that most of the class have the wrong idea about the dam question. He has immersed himself in the class discussions taking place in groups and by move 16 he needs to help pupils internalise the correct concept, using h.d.g. He introduces the 1 foot high dam! It seems to have achieved the desired result.

But pupil 5 uses P=F/A to reason that the 1 foot dam with bigger A should have smaller P without considering what F means in this equation. Misusing equations in this way is very common in year 10 and 11. Move 20 indicates that Roger is reflecting in action (Schon 1983, 1987). This pupil's suggestion has been un-anticipated by him and needs careful consideration because it seems very plausible to the class. He comes up with an improved model, taking time to draw diagrams on the whiteboard. Roger is a teacher who reflects in and on action in his class room. He is able to react to pupil backtalk, and analyse a problem by reframing the answer using the pupil's perspective. This helps him to design new ways, in action, for the class to see the correct physics ideas. This is a high level skill that Michael would like to acquire and use in his teaching. Part of the project with Michael is to help him start to develop this skill.

Pupil 6 takes up the area theme to argue for the wrong answer! Up until now roger has been using interactive/dialogic communication approach and the patterns of IRP, IRFRF chains, would confirm this. (Mortimer and Scott 2003). By move 24 Roger has decide to change the communication approach to non-interactive/authoritative (Mortimer and Scott 2003), to bring the activity to a close.

This was not planned to take up 9 minutes of class time. Open interactive dialogue will throw up many ideas that need careful consideration and this is time consuming. Many of the class used the formula h.d.g to get the correct answer straight away, so may have been bored by the process of analysis and discussion between Roger and 6 pupils in the class.

The next activity involved the classic demo of tube of water with holes at varying depths, which are unplugged and flow rates are compared. Following this lesson I considered whether the sequencing of the demo and the question designed to expose a common misconception, might have been reversed.

The idea of having a data source, or practical demo experience, an activity or visual stimulus for the class to consider before explanation begins, occurred to me after the lesson. The problem of what I now call "cognitive noise", (the contributions from pupils that take the class away from the planned lesson sequence,) in interactive/dialogic teaching, is a difficult one to solve. This action research project is trying to find ways to avoid lots of cognitive noise. The work with Roger has been concerned with exploring this issue.

Interestingly the post lesson interview data saw Roger express the opposite view.

> *Interviewer. How did you as you choose the activities that you used today?*
>
> *Roger. It is a right area for dealing with misconceptions, just in terms of actually realising that the whole depth pressure thing opens, opens up a whole world of confusion. So I took advantage of that as far as I could. The order was important; in*

terms of recap to them, thinking themselves, discussing it and then coming back to the demo, to break it up a little bit so lesson not all talking.

Roger was happy with the discussion, he wanted the class to think and express their thoughts. The demo was to reinforce the key idea after the misconceptions had been aired for all to consider.

He added talking about misconceptions,

Roger. I don't plan to handle misconceptions explicitly, I think of them as I am going along.

As I have said he can deal with contingency effectively and often imaginatively.

Interviewer. If you had as much planning time as you wanted. How would you use this time?

Roger. What I find easy is subject knowledge and all that stuff, I don't need to plan that, and I know the demos and practical examples I will use. I would try and focus on doing assessment better in the lesson, more effectively assessing them all as I went along, be that through little exercises like written tasks or using whiteboards or even things I don't have time to sit down and plan.

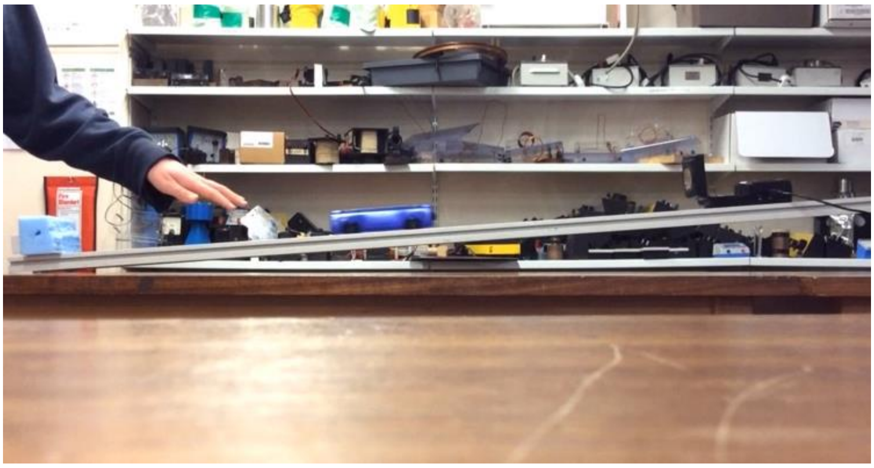
He is committed to assessing as the lesson progresses and one approach to achieve this objective is interactive/dialogic communication.

Appendix 2.D

Nicola Audio Data February 2018

I continue with my longitudinal study of Nicola explaining physics. In this episode I present her with a video and some data from a data-logger. A v/t graph for a cart rolling up and down hill is shown. She has never seen this scenario with me before.

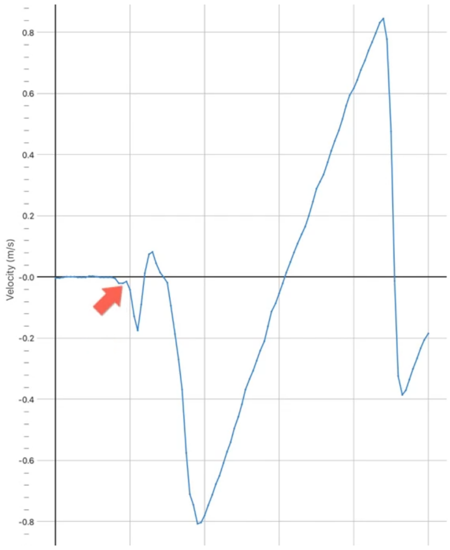
1. *I'm just pushing the cars up the hill. Now, the motion sensor produced that graph, and I'm plotting velocity time. What I think will be good, to start off with, is for you to tell me what that graph is showing. Try and relate it back to the video. It's similar to the exercise that you did back in the summer. Are you happy with that?*



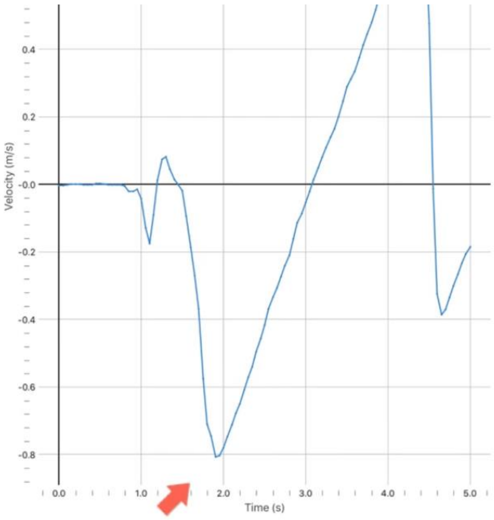
2. *Nicola: Yes.*
3. *Interviewer: If you remember the tools that you've got. You've got a pointy tool and you've got a writing tool. You were better at that than I was, so just go ahead.*

I introduce the problem and remind Nicola of the tools she can use in the explaining software.

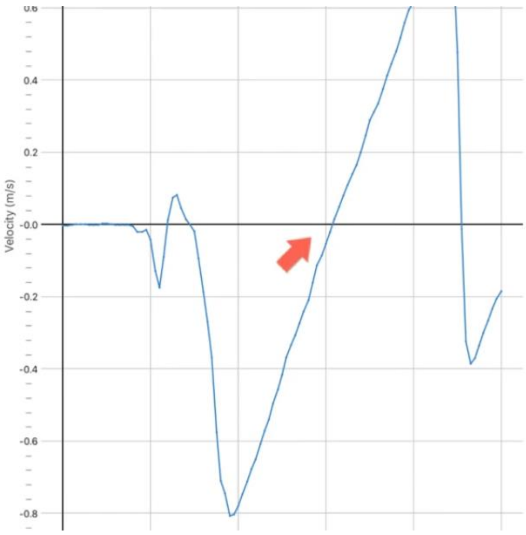
4. *Nicola: This is set up so the direction is doing it the opposite way around from what I tend to explain. This bit here, will be the little impulse you send, which is not a perfect forward clearly.*



The below and the above the line would be the direction it is moving, and obviously, the further away from the line is the higher the velocity in that specific direction. Here would be the little, I think, impulse that you've given to it, it's a bit of a wiggle, I'd assume. That explains that little wiggle. Here would be the maximum velocity and be towards the motion sensor of direction.



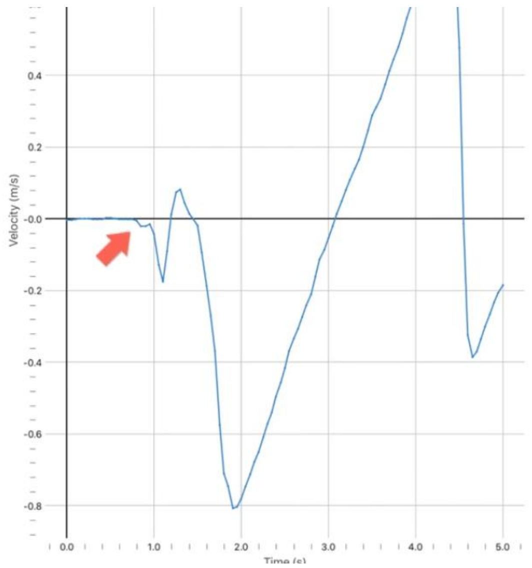
Here is the point where the velocity becomes zero because it's changing its direction, so at some point it has become stopped to change direction.



It stops for a millisecond so there's no difference in there. It gets straight up to the maximum velocity away from the motion sensor and it slows down to a stop. Then, you push it back when you grab it. I think that's what's happening there. You push it back towards the motion sensor a little bit.

This general description is fine, she is comfortable with the concept of velocity. But she has not identified the point where the push was removed from the cart.

5. **Interviewer:** *All right. Can you show me on the graph where I let go of the trolley?*
6. **Nicola:** *You let go I'd say probably here. There. That point there.*

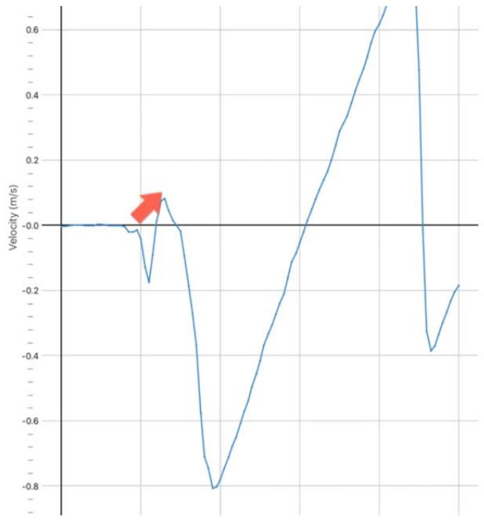


7. **Interviewer:** *Okay. Can you just tell me again why you think I let go of it there?*

I am using the video and v/t together to encourage Nicola to reflect on her answer. I am working hard not to give any signs that her answer is incorrect.

8. **Nicola:** *Because that is where the velocity continues to-- Hang on, because the velocity is zero, so that's where it's still. It must have been there. From zero, where it's a straight velocity, it's increasing at a constant rate essentially. That's where you wouldn't have any of it. That's where you let go.*
9. **Interviewer:** *So, where's the point I let go then? There?*

Nicola reflects and changes her mind.



10. **Nicola:** *Yes. Wait. No, hang on. No. It's from this point definitely, because from the forward point that's where it's going in this direction.*

She is confused between where the video shows the cart moving up hill and v/t data showing the wobbling before it is finally pushed. The initial wiggle is causing the problem for her.

11. **Interviewer:** *Okay. Just put the arrow on where I let go.*
12. **Nicola:** *There.*

13. Interviewer: *All right. The top peak there? Okay. Awesome.*
14. Nicola: *I'm talking about the red arrow.*
15. Interviewer: *All right. Good. That's fine. Now, between these two points on the graph, can you tell me what's happening there?*
16. Nicola: *Between these two points?*
17. Interviewer: *Yes, between the maximum negative velocity and the maximum positive velocity.*

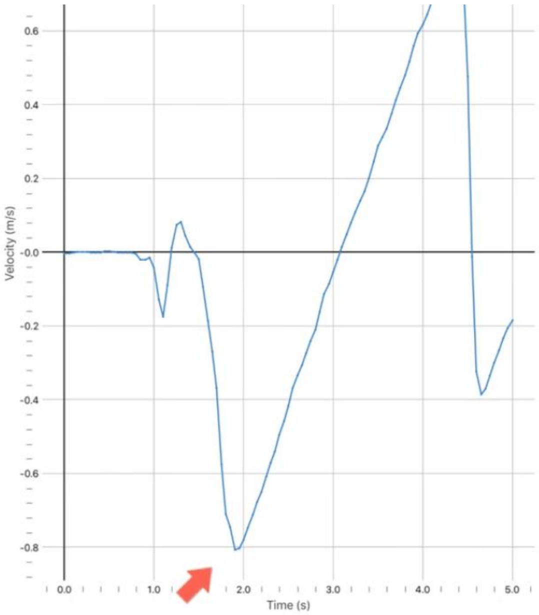
I want her to reflect on this final answer by thinking about the meaning of the main section of the graph.

18. Nicola: *That is where it's slow down right to the top. If we go back to the video. Can we?*

She wants to relate the v/t data to motion as seen in video recording, which she always likes to do. There is a lot of dialogue while she works out how the v/t graph synchronises with the video

19. Nicola: *Okay. This is the maximum velocity and the minute you do let go, it should start slowing down. So, this must be when you let go.*
20. Interviewer: *Where? Use the pointy tool so I can record it. You just press the point. That's it. So, now you're changing mind?*
21. Nicola: *I'm changing my mind because as soon as you let go, it would begin to slow down.*

The hint has caused her to reconsider her explanation and finally she gets the correct answer.



22. Interviewer: *Okay. Cool. That's your final answer?*
23. Nicola: *Yes.*

The video and v/t data had to be considered together by Nicola for her to make sense and be able to answer my question of where did I let go? I make a comment;

24. **Interviewer:** *Interesting that the video helped you change your answer there. It's interesting. Now, let me go back to the question I just asked you. What happens between that point where it's maximum negative to maximum positive?*

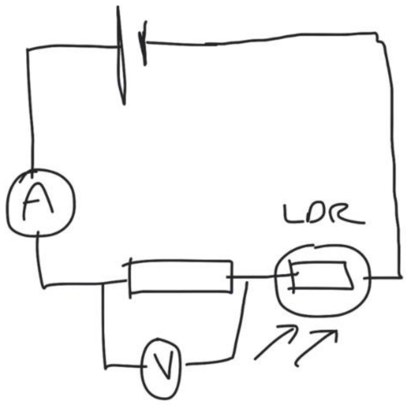
She goes through the explanation again.

25. **Nicola:** *The minute you let go here, that's the maximum positive because you sped it up here. The maximum positive is here and then from then, it's going to begin to slow down because it's working against gravity up the slope until it gets to zero where it stopped because the gravity has won and it's gone the other way down the slope. This is the maximum velocity it's reached with working with gravity down the slope until you catch it again or you stopped it.*

She does not draw a free-body diagram and work from forces as she did in the summer. She was also happy talking about free-body diagrams in October. They are not part of her problem solving schema in February. I would suggest that lack of practice has resulted in her using more colloquial language, working against gravity.

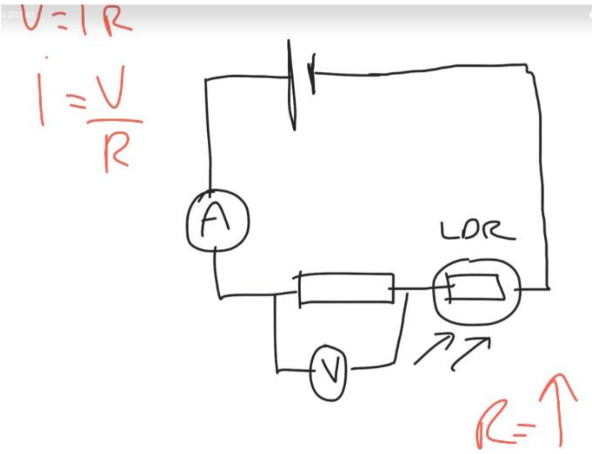
I had not studied electricity with Nicola since July. I wanted to examine her model structures and explanation making in an area of physics she declared to have problems with.

I drew a potential divider circuit with an LDR. I gave her some data on behaviour of LDR components. This is a circuit we studied back in July on the booster course.



1. **Interviewer:** *Okay, great. One last little challenge for you, and this is a circuit, a circuit theory challenge, all right? We've got a simple series circuit here. Now, I'd like you to begin by-- you can do this in any way you like, but I want you to try and explain what would happen to the variables that we used to describe circuit behaviour? What would happen to those variables in this circuit, if I block the light, if I reduce the light on the LDR?*
2. **Nicola:** *If you reduce the light on the LDR, if you reduce the light, the resistance would increase, right? That's what you said?*
3. **Interviewer:** *Yes.*

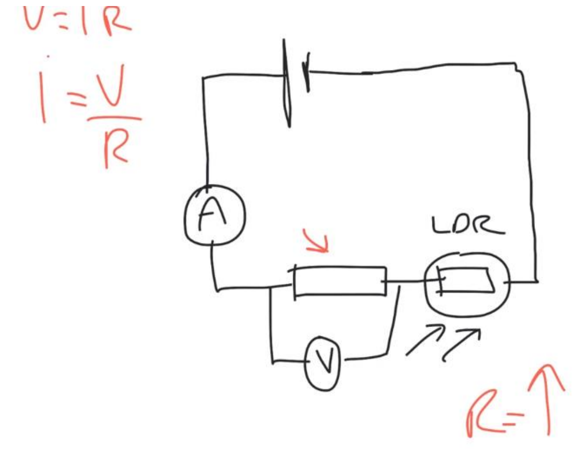
4. **Nicola:** *Okay, so reduce light, resistance goes up here. The resistance will stay the same here because nothing's changed. If there is a sense or the way I generally work it out without just-- what have we done? Okay, the resistance increase is so called V=IR, and I know that if I do I=V/R, the bigger the resistance, the smaller the current, and the voltage is staying the same because we've only got a certain amount of voltage.*



5. **Interviewer:** *That's the voltage of the power supply, right?*
6. **Nicola:** *Yes, but across this resistor, if the current decreases which we just said that has the higher resistance in the thing, the smaller the current in the circuit. So if the current decreases, the voltage would also decrease in the resistor (fixed resistor).*

She uses resistance change of LDR to argue that total current through both resistors reduces. This is correct but she becomes unsettled when I switch attention to the potential difference across the LDR.

7. **Interviewer:** *What are you saying about the voltmeter reading, that voltmeter reading?*
8. **Nicola:** *That would decrease.*



She has explained that the voltmeter connected across the fixed resistor in series with the LDR would read smaller voltage. This is indeed correct. I push her further.

9. **Interviewer:** *That would decrease, okay. What would happen if I move the voltmeter and put it across the LDR?*

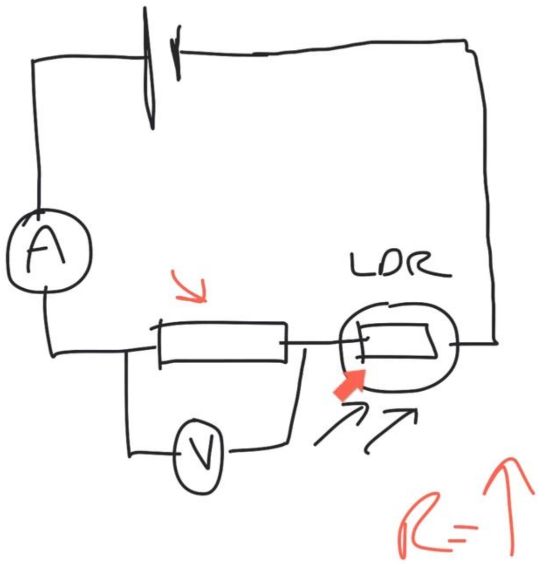
She is thinking hard about this last statement. She is unsettled.

10. Nicola: *The same thing, the voltage would decrease.*
11. Interviewer: *Okay, both voltages decrease?*

I summarise here to cause further reflection. We used KIrchoff's laws in the summer to create a model for circuit analysis; Ohm's law and rules for adding resistance were built into this. The model dealt with energy and charge conservation in circuits.

She is using Ohms law only and in a very naïve way. Her model is that the smaller the current the smaller the voltage and indeed if the resistance is fixed this can be the case. But she needs to talk about voltage across a resistance and flow through it. I = V/R is a good way to think about this, but the condition is that R is fixed and the LDR resistance has changed. A more careful and thoughtful analysis is required.

12. Nicola: *Hang on. No, this, what we were talking about here if the [laughs] no, yes, no. I've gone wrong-- If the resistance increases here-*
13. Interviewer: *Of the LDR?*
14. Nicola: *-of the LDR, sorry, I'll start pointing.*
15. Interviewer: *If you point, that's easier.*



I want her to interact with the diagram to identify points between which there is a voltage that she is considering. This does not happen. She is pointing to LDR now.

16. Nicola: *If the resistance increases here, and then what I was just talking about is to do with this resistor, this LDR, not this one.*

She is arguing that her previous narrative referred to the LDR not the other fixed resistor. She is using a model which does not consider that the current flow is the same in both resistors.

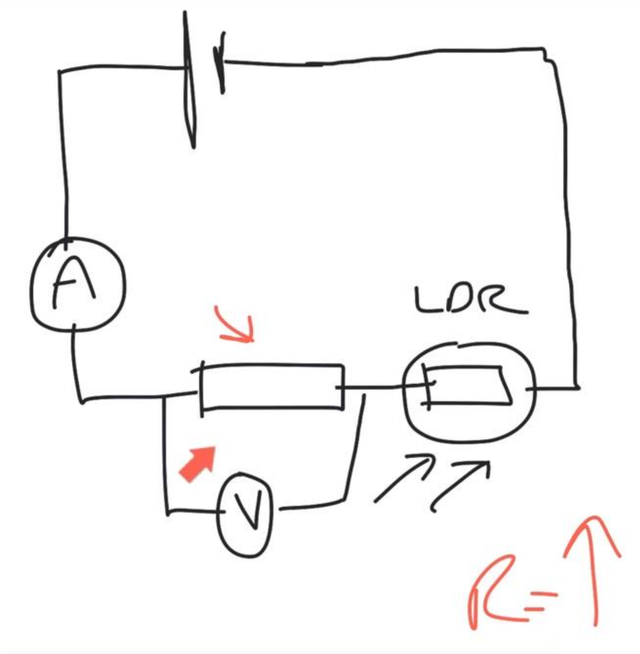
She now wants to claim that smaller flow through LDR will be associated with smaller potential difference, totally ignoring the fact that its resistance has increased! This type of analysis has been well analysed in the literature VIENNOT ET ALL

17. Interviewer: *Okay.*

She concentrates on the LDR, saying the current through it decreases and the voltage across it decreases using Ohms law.

18. Nicola: *If the voltage of this one decreases, I said that right, yes? If the voltage of this one decreases because the current decreased, then the potential difference of-- well, then the total voltage is the sum of these two voltages, so this one would increase.*

She takes her previous argument and applies the result to the voltage across the LDR.



19. Interviewer: *The voltage--*
20. Nicola: *This voltmeter reading would increase, because this voltage would decrease.*

She is now pointing to the fixed resistor. So using I=V/R vaguely, she argues that the voltage across LDR decreases as its resistance goes up. V is not identified clearly. Combining this result with the Voltage rule, she concludes the opposite of her first analysis.

21. Interviewer: *Okay, that's the opposite of what you said before?*
22. Nicola: *It's the opposite of what I said before, because I was applying this formula (points to I=V/R on screen) to the wrong one. [laughs]*

She uses the formulae in a similar way to pupils, rather than thinking about flow and potential difference concepts. She uses I= V/R to argue about potential difference without considering the conservation laws of charge and energy together.

23. Interviewer: *Okay. All right, okay. What would you say about the-- If I had two voltmeters, this might help if I actually draw it in, if I have another voltmeter here, 5.2* *and if I actually measure the voltage across there as well, how would you relate those three voltmeter readings?*

24. **Nicola:** *This voltmeter reading should be this one plus this one.*
25. **Interviewer:** *Why do you say that?*
26. **Nicola:** *Because it's a series circuit. The total, which would be this one, is V1 + V2.*
27. **Interviewer:** *Okay, that's a rule that you remember?*
28. **Nicola:** *Yes.*
29. **Interviewer:** *Okay. What about the current here in this one, and the current before the resistor there?*
30. **Nicola:** *It should be the same.*
31. **Interviewer:** *Why would they be the same?*
32. **Nicola:** *Because the electrons in series circuit, the electrons are all going through the same-- they should be the same everywhere.*

Line 26 and 32 needed further un-picking but I decided not to do that at this stage. I wanted to investigate her recall of the circuit model a bit more so I asked her about current flow in the voltmeter but she could not recall model details to deal with this question.

Working in this way with the circuit and interactive tools, and recording the explanation has allowed me to use VSRefl to explore misconceptions.

Appendix 3.A

Michael circuits lesson; questioning about circuits with pupils.

Video clip: power shutdown dialogue. Duration 1min 25secs.

Video Narrative	Questioning Analysis
7. Michael begins with a question to the class. “What did we find out, was there a difference in the brightness of the bulbs?”	I move relating to practical from first lesson of this two lesson sequence I observed. There is no discussion to improve this I move. It is not an I(d) move.
8. Pupil 1 responds ….yeh	R bald response.
9. Michael replies, “what was the difference?”	So Michael makes P move.
10. An inaudible recall type reply is made, Michael summarises by repeating answer, “it was less bright when there were two bulbs.”	R move with summary or “revoicing” statement from Michael.
11. “Let’s see because we actually talked about this before at key stage III,” Michael adds.	
12. “Can anyone explain why it might be dimmer when there are two bulbs?” Michael asks.	I move, this time it’s a better quality I move. He is encouraging the pupils to explain.

13. Pupil 2 replies," because it sharing out the same amount of power as before but between two bulbs."	R move.
14. Michael interrupts before answer finished, Pupil2 is using the word Watts but his dialogue is lost… "You keep using the word power,	E(c) (evaluate but shut down dialogue) move from Michael.
15. Pupil 2 interrupts with the word "electricity "	F move from Michael with R move from pupil 2. A longer F move from Michael
16. "can I just warn you that it has a very specific meaning…." Michael adds, "can we avoid using the word power today and we'll come onto power later."	
17. "Let's talk about it in terms of energy," Michael urges…	I(d) move. This is good to see from Michael.
18. Pupil 2 continues his dialogue. He adapts his previous answer. "The same amount of energy as before but to more bulbs, so the two bulbs are having to share out….."	R move from Pupil 2.
Michael summarises emphatically, "and that's exactly what you learn at key stage III, two bulbs have to share the energy, it's the same amount of energy and therefore the bulbs get dimmer, and that makes sense."	F(c) Michael has achieved his teaching/learning objective in this activity.

Appendix 3.B

Action Research Project: questioning, explanation, practical a new take on things…

Thank you for agreeing to take part in this project. This is very much a work in progress and you are among the first teachers that I have tried these ideas out on!

After an initial training workshop, phase 1, some of you may want to volunteer for the classroom phase.

Just to confirm what we discussed when you agreed to participate.

1. You will be interviewed pre and post workshop and a digital recording made. You will have access to the transcript and raw data. This will not be available in the public domain and your identity remain anonymous in any subsequent analysis/writing.
2. You may be filmed and the same principles as outlined in 1 above will be followed. The videos will not be available for general viewing.
3. All data will be stored on a secure server.
4. The same procedures will be followed for phase 2.

Workshop

1. You will learn how to use screen casting as a teaching and learning tool, but more importantly as a way of encouraging your pupils to make meaningful explanations. I have enclosed some data for you to look at before the workshop.
2. Small practical demos, which produce interesting data, can be generated very easily using new data logging technology. This technology is not expensive and is relatively easy-to-use. An engaging demonstration that produces data, can stimulate high-quality dialogue between teacher and pupils, and amongst pupils themselves. Using such a demonstration, I want to suggest some new ways of structuring questioning in the classroom.
3. We will begin to explore ways in which we can integrate questioning, explanation and practical demonstration into our teaching activities in physics.

Before you attend:

To get the most from this workshop you need to spend half an hour on the following.

1. Can you complete and email me the questionnaire enclosed. Just three questions but your thoughts and opinions are essential. They will allow me to focus on areas that I need to develop given your views at the moment.
2. Look at the 4 samples of screen casting from my work with year my year 11 this year. We will be doing some work with these samples.
3. For the questioning activities, the physics we will be working with will be in the area covered in these videos. You may have questions about this area of physics given your present understanding. Prepare these for another activity.

Classroom Practice Phase

Those of you who carry on into the classroom phase; I will arrange an observation schedule and sort out equipment requirements and specific training for practical demonstrations. I will arrange video recording, which will be unobtrusive. I will write field notes in the lesson.

Workshop Background

In this workshop I want to show you techniques to help us as teachers watch, listen and talk more in class. This can help pupils make meaning and learn. Teachers have to speak enough to introduce and explain ideas. We must not talk too much though. We should want our pupils to do a lot of thinking, talking and explaining, when they are with us in class. The people who want to learn need to talk the most and that should be the pupils. Pupils need questions answered, not us. However, there must be phases in the lesson where we are authoritative, so that science ideas and concepts can be introduced. I am thinking about a flipped classroom approach to help with this issue, freeing more time in lessons for dialogue with and between pupils.

The teacher in their role must plan and create learning activities/experiences, diagnose misconceptions and help pupils make meaning with science ideas. The pupils must learn to accommodate science ideas and be able to use them to explain. The pupil needs to make meaning for effective understanding, we cannot magic content/understanding into their brains. We want to avoid mindless cramming of ideas.

The workshop has three interlocking themes.

Learning to think about Explanation

We will learn to use screencasting, sounds complicated it isn't! SCreencasting homework, some examples supplied for analysis, will be studies. WE will use for AfL and AfT, assessment for teaching, because we need to react to what our pupils are saying, and create further classroom activities based on what they are saying. What we want is for them to make explanations. The Simulation screencast is an example but we could use whiteboards, apps like explain everything, we could ask them to write some text, or some equations….

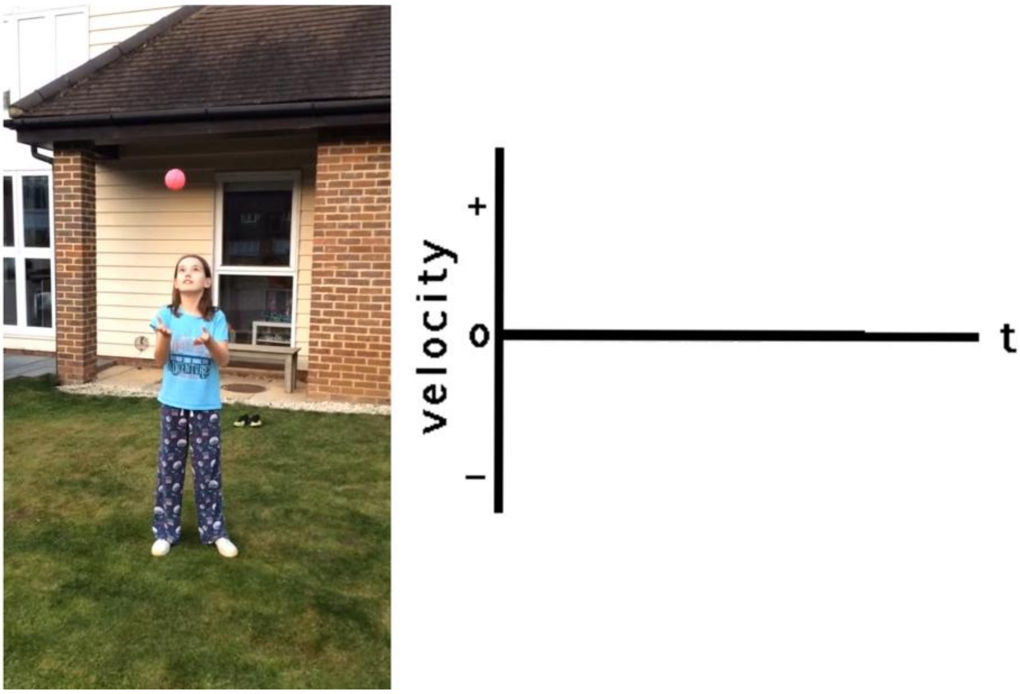
Creating a talking point

We will see how to do demos with new tech that allows data to be processed and available quickly. We can practice this technique in the workshop. Then we learn about PEOR, predicting, Explaining, Observing, Reacting sequence. This will stimulate dialogue and good questioning between us and our pupils.

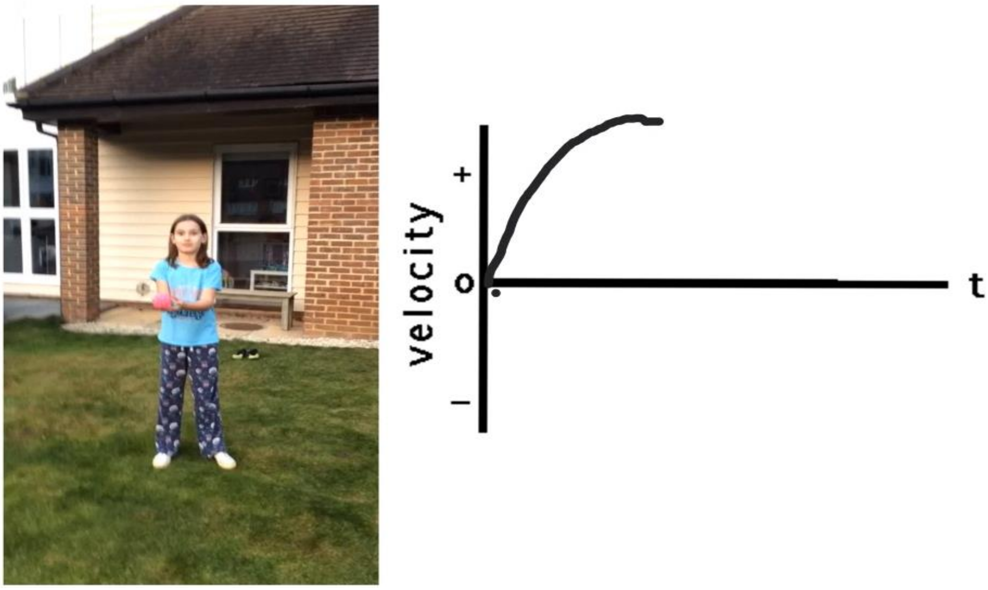
Questions and Questioning..

Interactive/dialogic and Interactive/Authoritative patterns, what are these and how do we develop them? Questioning for AfL and AfT. We will try to practise these forms in the classroom as we study physics. I do not want this to be artificial in any way, so will try to create patterns of discourse with you as pupils.

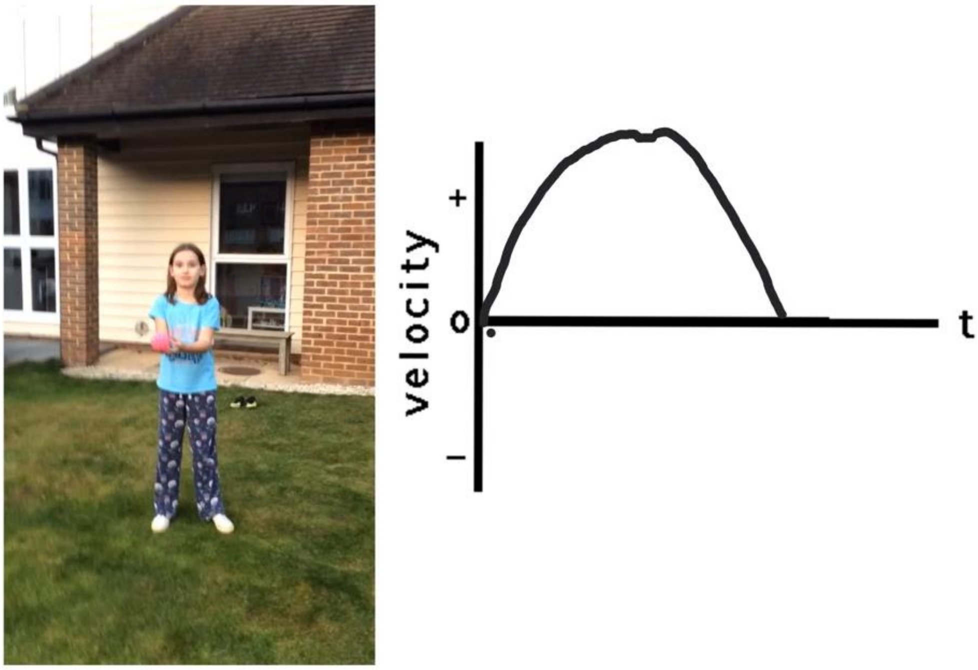
Appendix 3.C



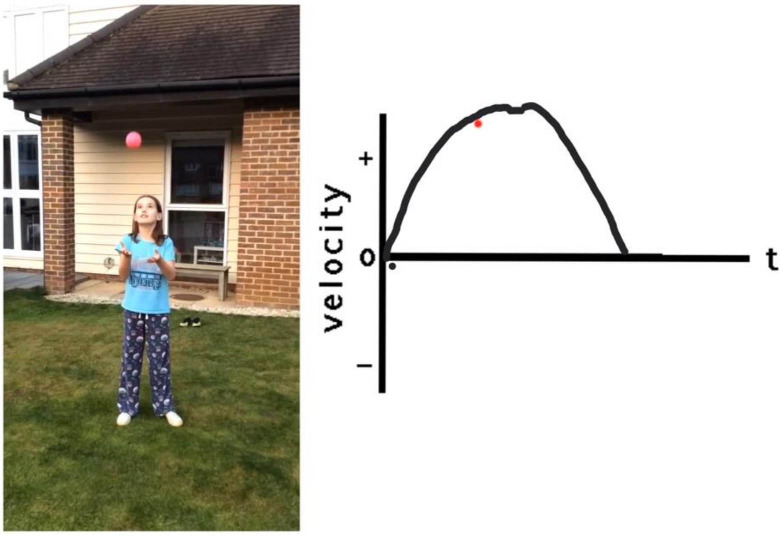
Video and Motion graph



“At the top the ball is at rest”.

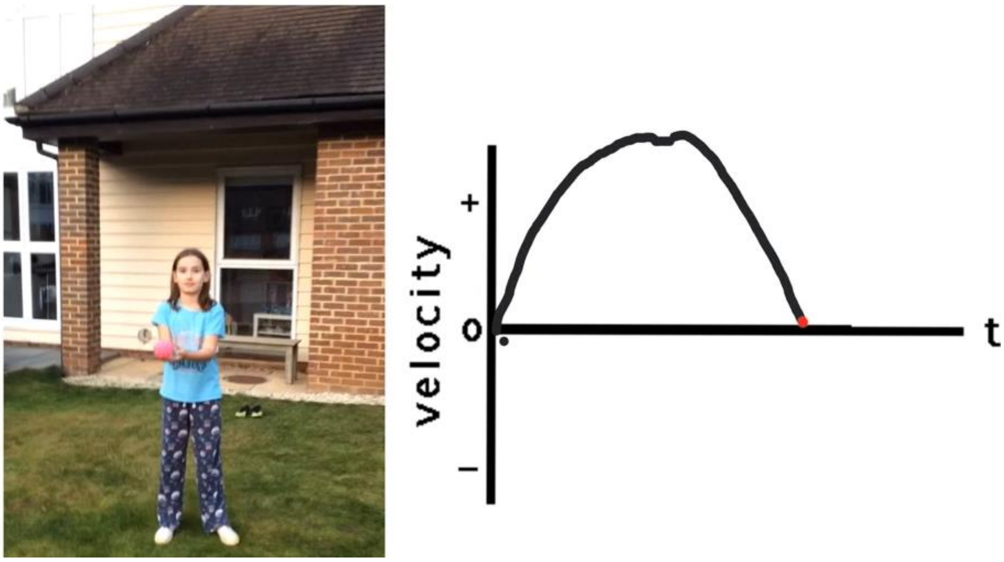


“The ball velocity goes to zero as it goes back to starting point”.

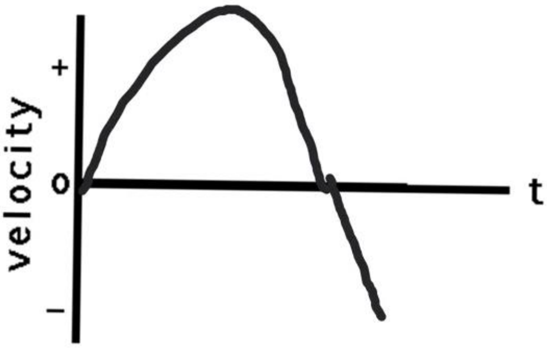


“We can follow on the graph the movement of the ball, at the very top there is no velocity”.

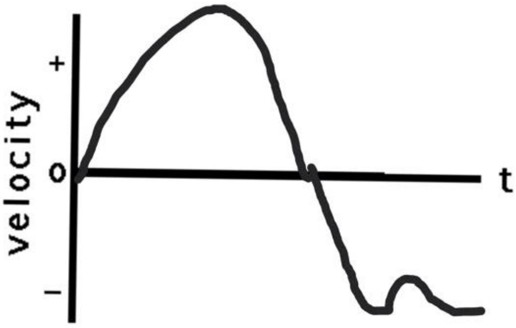
Synchronising video and the graph story is a thinking strategy I try to encourage as the constant acceleration model is explored.



“Then it falls back towards the starting point”. Michael indicates the starting point on his graph.



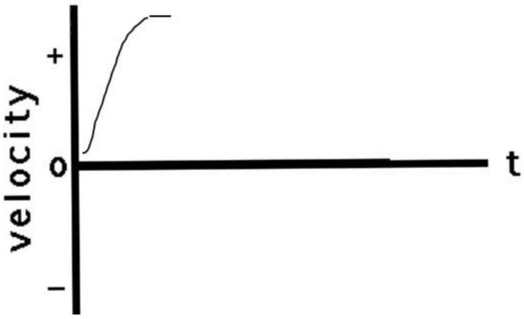
"When it goes past the starting point the velocity is negative".



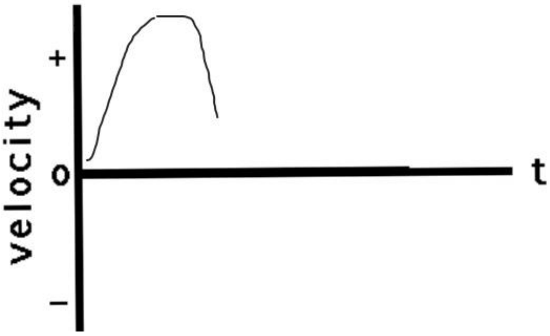
"There is a small bounce then it remains where it is on the ground".

Appendix 3.D

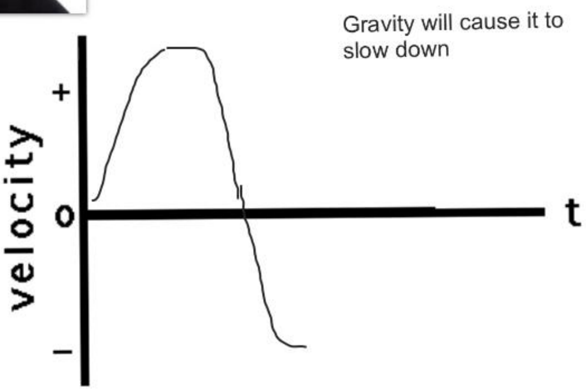
There is a video of the pupil throwing and catching the calculator.



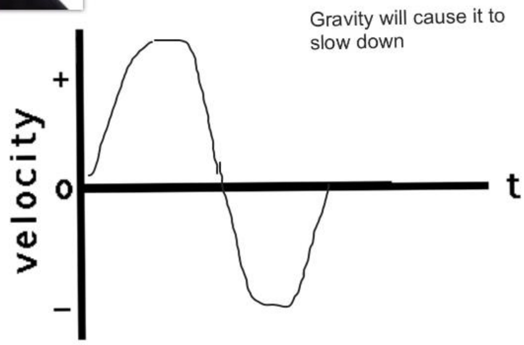
When it accelerates it will go up. That’s the force that he put on the object.



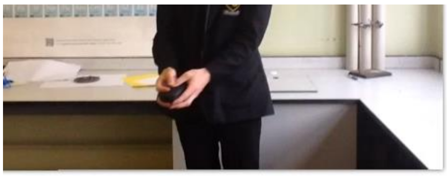
And then when it loses the force it is still going up… its just losing acceleration.

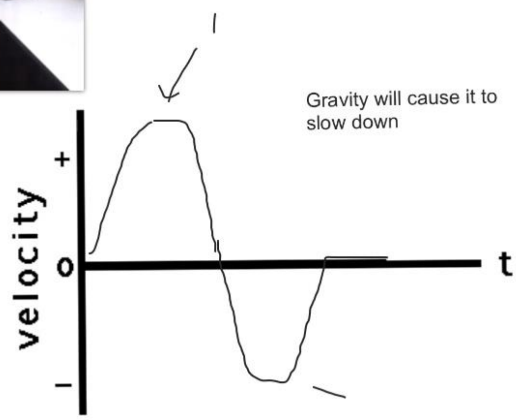


Then it goes down to his hands.

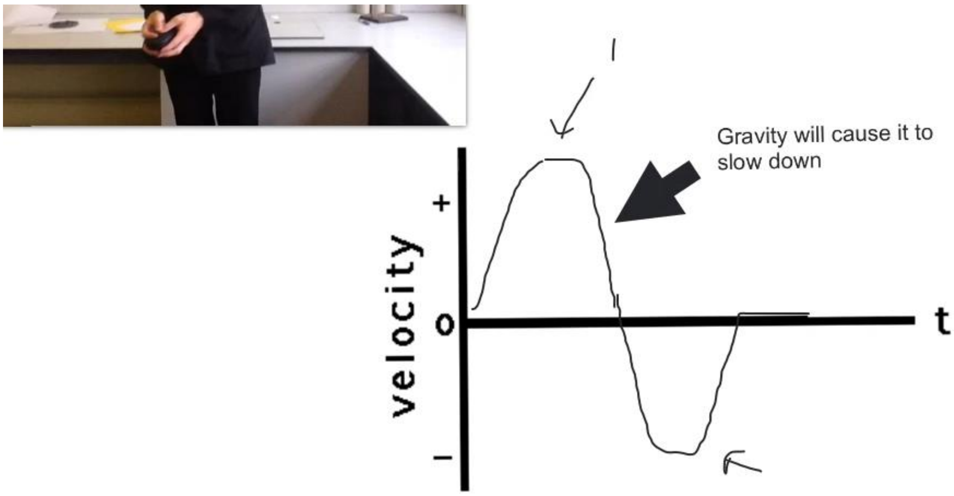


Then it gets slower towards his hand then stops. While he is holding it goes across.

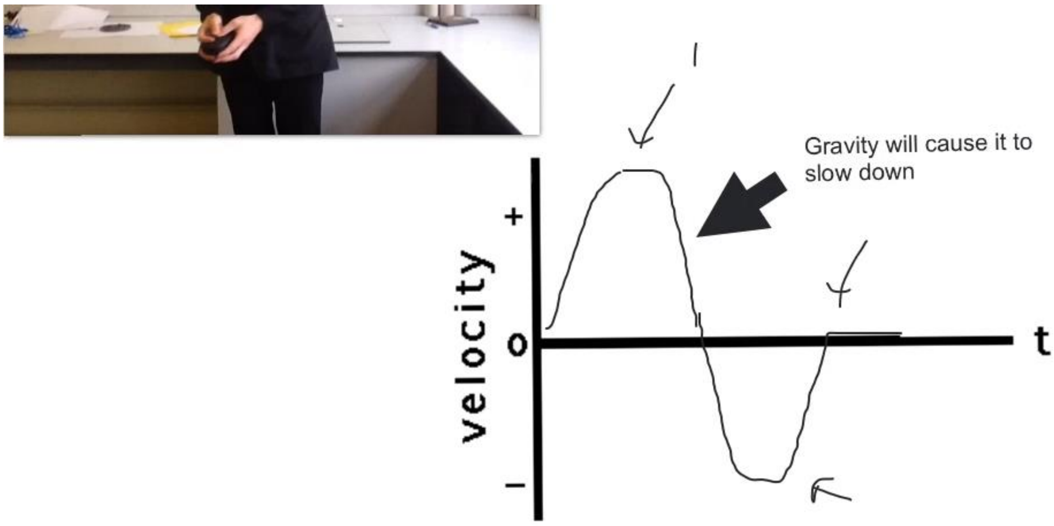




Here is when his force is stopped being applied.



Here is when its gone down and then started decelerating down..



And this point is where he has caught it.

Appendix 3.E

	NOS	Teaching	Learning
Michael	Michael was informed in most NOS beliefs, but the scientific method was a held belief, classified naïve.	Michael is a head of science, a Biologist and experienced teacher. Very organised and structures lessons and his teaching has been influenced recently by a philosophy project. Emphasis on explaining and thinking. Traditional/elements of the constructivist.	Again assessment for learning is in his blood. Strategies for this are employed, whiteboards and teacher questioning. Group work is used and he interacts with pupils individually. Process/ Constructivist beliefs for learning.

Tsai Classification, teaching style, learning, NOS

	Teaching beliefs	Learning beliefs	NOS beliefs
Traditional	Transferring knowledge, providing clear definition; practising problems, presenting scientific truths.	Transferring knowledge; memorising formula, definition, keywords and facts. Passive listening; finding the right answer; accurate calculation.	Wants an accurate description; neutral or objective observations; objective interpretations; truths.
Process	Teaching the scientific method; following problem	Understanding the scientific method; problem solving	The scientific method; codified procedures; process

	solving procedures;	procedures;	of discovery; following scientific rules.
Constructivist	Helping Michaels make interpretations- construct knowledge; providing authentic experiences; interacting with Michaels; encouraging discussion and cooperative learning; paying attention to prior knowledge or misconceptions.	Making interpretations;- constructing personal understanding; exploring authentic experiences; relating to prior knowledge or experiences.	Invented reality; imaginative acts; theory laden observations; are constructed through social negotiations.

Appendix 3.F

VSReflection 19 Dec 17 Michael Radioactivity Lesson

Key idea: Activity. How can we relate dice sim to data collected? While doing this avoid the common misconception about half life.

A. Probability Discussion

1. Why are curves so different?
2. Relation to radioactive decay. Emily episode. What do you mean by half-life? Did you answer pupil's question?

B. 1/11 Chance episode 00:35

1. How do you feel about this episode?

C. Probability Maise episode 1:07

1. Do you think you are going out next?

D. Pa Discussion

Segment begins, 3:38.

1. You are comparing the dice simulation graph with the Pa decay data. Which graph shows an activity?
2. John talks about half-life episode. 4:25 " it goes up and then it halves each time…isn't that why they call it half-life?" Listen to your dialogue. You are asking questions, do you get the answer you want?
3. You then move on to compare rough and smooth curves. 4:57. Trend line comment made by girl. Then randomness comment made with lots of decay comment made. Can you use activity concept here?
4. Define half-life and connect to data. The pupil answer is confused.
5. Connection of half-life to probability. Good episode.
6. The SIM episode. 11:55 100 v 1000 nuclei. Its faster for 100! Misconception.

Appendix 3.G

I now revisited the question of 100 versus 1000 dice and half –life.

1. ***Michael:*** *The fact that it would take the same amount of time to decay.*
2. ***Interviewer:*** *Yes. This was the 1,000 versus the 100 nuclei. There was a young lady who said it would be faster if it was a 100.*
3. ***Michael:*** *Okay.*
4. ***Interviewer:*** *There was a young lad, who was talking about probability and that it is the same probability. I think that the issue was the language faster to decay.*
5. ***Michael:*** *We could have talked about activity at that point, couldn't we? That would have been-*

I was pleased by this response. Michael was applying the new concept and finding it fruitful. (Posner…)

6. ***Interviewer:*** *You could have talked about Activity, it would have differentiated the two samples because the 1,000 and the 100 were different in their initial activity.*
7. ***Michael:*** *But the probability is-*
8. ***Interviewer****: Okay. The half life-*
9. ***Michael:*** *- is the same, yes. I got it ,yes. That would be an interesting discussion.*
10. ***Interviewer:*** *The concept of activity-*
11. ***Michael:*** *Yes. I hadn't thought of that before. Yes, there's going to be less activity but the same probability, yes.*
12. ***Interviewer:*** *Rather than allow them to say it decays- decay faster I think means more clicks for a second, right?*
13. ***Michael:*** *Yes it does.*
14. ***Interviewer:*** *We're dealing with a different concept.*
15. ***Michael:*** *Completely. That's something I might go back with them. Where we've just done our mock exam in this. The only thing is the level of the questions in the mock exam are much simpler than this. You still want them to have a better understanding*

of what's happening. Yes, when we go back through the mock, I'll discuss that activity I think.

Appendix 3.H

Coaching Content

1. Shaking torch: Michael did not focus on the key features of the V/t graph. The peak voltage values were not seen as significant. He did notice the polarity switch and that the area of the peaks were different and tied to explain these features.
2. Drop magnet in tube: The relation of the short drop magnet demo to the shaking torch data was apparent. He made some explanation of identical peak voltages using terminal velocity concept.
3. The transformer at high frequency: This was a puzzling demo without the flux rule to help. So he could not predict peak induced voltage change on doubling/halving of primary voltage frequency. He could talk about change in Voltage with some help. This example allowed me to focus on the flux rule. I had to emphasise that we were working like Faraday, using a simple conceptual model and so could not really talk easily about forces on charges. This was not a problem as engineers work meaningfully with the flux rule.
4. Oscillating bar magnet: He struggled to infer that two N poles together might produce twice the field strength at a fixed point. We checked this with magnetic flux density probe. WE worked at understanding that for mass on spring increasing mass means lower oscillating frequency. Again his analysis was energy based and he struggled with explanation. He did conclude that maybe the increased B would be cancelled by lower frequency when it comes to predicting peak induced voltage.

Appendix 3.I

I will illustrate the process behind the assignment of the data codes, by considering some examples of the analysis.

T3.2[1+2] Page18

This code was assigned after consideration of VSReflection1 data. Michael had produced an explanation of a ball thrown into the air. The explanation was captured using the "explain everything" software. I had looked at the video and prepared the coaching activity to follow on from our VSReflection1.

	Definition of Link
1	Michael's **existing** SMK/PCK leads to questions and discussion. VSReflection 1 helps.
2	Michael reflects on tutorial episode and develops PSMK/PPCK.
3	Tutorial experience influences class room behaviour.
4	Michael's **modified** PSMK/PPCK influences class room behaviour.
5	Michael's PSMK/PPCK changes on reflection on practice. Aided by VSR2 and post lesson interview.
6	Reflection on lesson data determines salient outcome.
7	Previous or new outcomes affect teaching. All reflection data important.
8	PSMK/PPCK modified by reflection on outcomes.
9	

	Deciding after reflection what is salient using PSMK/PPCK.

Table 3.1

Above is a copy of Table 3.1 which shows the clues to identify each of the links in the IMTPG. These are based on the work of Justi and van Driel. Link 1 captures the notion that Michael is interacting with external coaching domain, to change its content. His explanation is providing “material for us to work on” (Ogborn et al. 1996:15) in the VSReflection1 process.

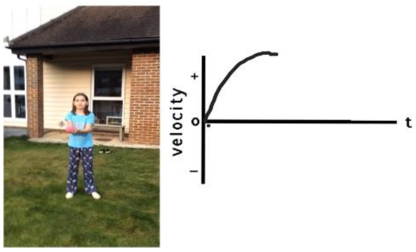


Fig 3.2

“At the top the ball is at rest”.

The quote and the image from his video allowed us to focus in on the process by which he made the explanation and the error he had made in the narrative. Looking at link 1 in Table 3.2 copied below, I was confident that Michael;

(c) Was thinking and asking questions during the reflection process,
(d) Purposeful discussion was allowing him to resolve the misconception and see that this might be how some of his pupils would think about this problem.

	Inferences from Data

1	Michael's **existing** SMK has been found wanting. VSReflection1 has led to Michael voicing questions and discussion of his misconceptions.
2	Michael reflected on tutorial and VSreflection1 as evidenced by excellent questioning episode in lesson. Some pupils had avoided his misconception, so Michael had a better understanding of the constant acceleration model, underpinning his teaching.
3	He used data-logging and the capture explanation technique in his lesson.
4	He was more dialogic during questioning episode about gradients of v/t graph. He was exploring ideas with pupils.
5	In VSReflection2 Michael reflected on what was a new physics teaching experience for him. He understood the pupils misconceptions because he had the same ones and now he knew how to address them in a classroom situation.

Table 3.2

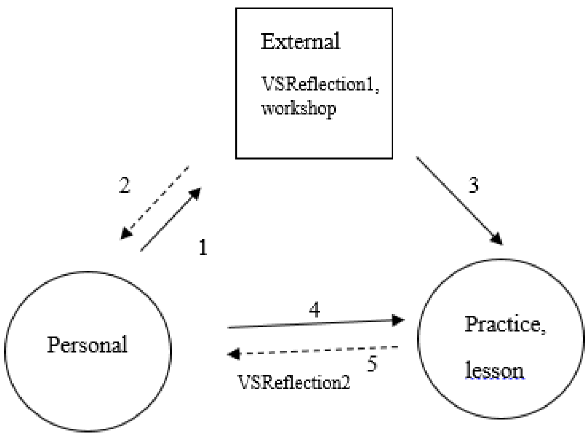
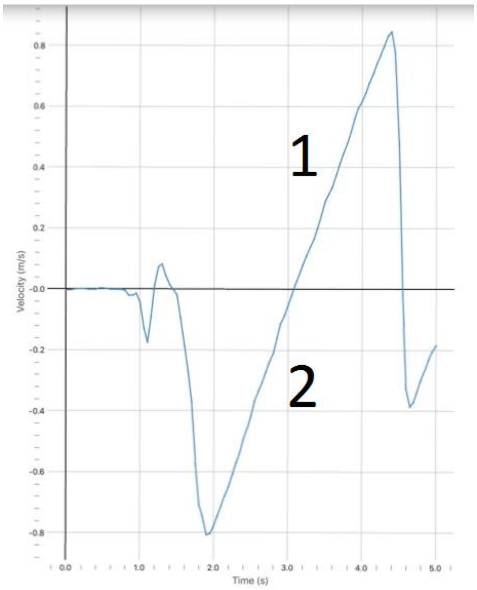


Fig. 3.10

At this stage I would start to draw the IMTPG icon, see above. Fig. 3.10. Link 1 is saying that changes in the external domain were brought about by Michael enacting ideas from his personal knowledge domain. The external domain is where I coach, and activities created will encourage reflection.

As Michael resolved the conflict between the graph peak and the claim that the ball was at rest, see figure above, I can infer the existence of link 2, Fig. 3.10.

T3.2[4+5] Page 24.



Michael. *Is the gradient of section 1 and 2 the same? T3.2[4+5]*

This was a very significant moment in AR1. In my field notes I wrote, "Michael asked a really good question." This was exciting and important because;

(a) I could see Michael was utilising ideas from our coaching session following VSReflecton1.
(b) He was asking a question that needed a thoughtful response from pupils, in contrast to his usual simple recall type questions.
(c) He was working with the data and following up on a misconception he had had in VSReflection1.

Link 4 is about enacting ideas from coaching and that is evident. His PPCK and PSMK have changed. Link 5 is concerned about reflecting in and on action. (Schon, 1987, 1995). When I observed this lesson I was not comfortable with Schonian coaching ideas. Writing this thesis I was pleased at how well Schon's coaching model helped me describe what I was doing with Michael.

T3.3[5+6] Page 34

14. *Michael:* *I was planning on demonstrating half-life using a data logger and using that to plot a graph. Then I was hoping to do something quite similar to the last sessions,(AR1).*

5 and 6 are reflection links between the domain of practice and consequence. This assignment is interesting because it points to the longitudinal effects evident in this project. I thought about whether this was strong enough evidence to claim a growth network for Michael, but decided that more evidence was needed.

Link 5, Table 3.1, reflects that AR1 reflections have modified Michael's personal knowledge domain. The evidence for this is very strong by the end of AR3. In Table 3.2 I record a clue which describes Michael reflecting on Activity an important outcome specific to AR2. When analysing my data sources I used table 3.1 and developed a new table for each cycle which captured key inferences and clue structure changes, for each AR cycle.

Link 6, Table 3.1, reflects that AR1 has produced salient outcomes for Michael. He likes the idea of working with data and developing explanations using models. This is still a vague notion in his mind but he wants to build the lesson on radioactivity using the same structure as the motion lesson.

I need to be sure he was not following a strong, but unintentional, steer from me and that he wanted to carry out the lesson mirroring AR1. This was an important ethical issue.

	Inferences from Data
1	In coaching Michael had ideas about randomness.
2	He plans to use Protactinium source and data-logging. He reflects on bumpiness of activity curve. DDAME is in mind from AR1.
3	He tries to model lesson structure on AR1 lesson. Content is largely derived from coaching.
4	He carries out interactive/dialogic activity on dice model. He demonstrates and captures activity data.
5	He reflects on meaning of Activity and how it can be used in the classroom to improve the activities he used.
6	He is convinced of the value of making explanations, examining them and using data to stimulate explanation making.

Table 3.3

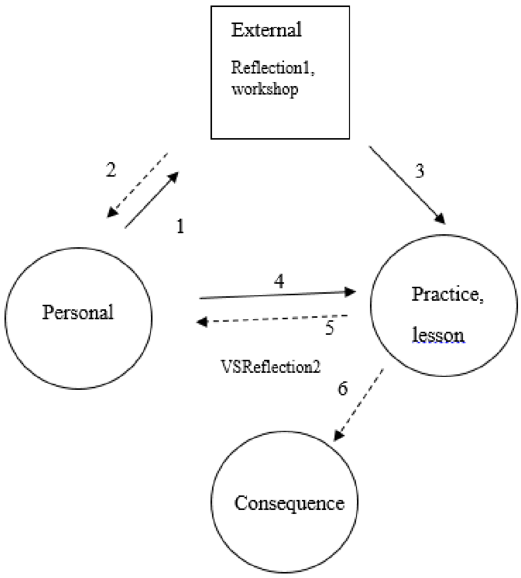


Fig. 3.13 IMTPG AR2

T3.3[3+4] Page 36

Dice model for decay. This involved the whole class, with Michael recording data on the whiteboard. Once again he asked good questions and made few errors. A nice touch was that he varied the probability of decay (1/6 to 1/3) and related results to shape of graph and half-life. Michael used IRE patterns of communication (Mortimer and Scott 2003) but the interaction engaged the pupils and they were thinking about randomness. This **was not simple** interactive/authoritative communication.

Enaction links are always easy to assign, and this was an important realisation in this project. I always had to work hard with the data to justify reflective links.

Michael used ideas, data capturing, random model of decay from coaching, a classic 3 link. Importantly link 4 says that ideas from coaching are now part of his personal knowledge domain. Michael had modified personal knowledge. New ideas and values are influencing what happens in the domain of practice, link 4.

T3.4[1+2+3] Page 46

By AR3 the captured reflective practicum methodology had evolved considerably. VSReflection followed by coaching was still a core element. As I have said earlier enaction links are easy to infer and by now I could see evidence for links 1 and 2 in the same data. I and 2 together describe a key element of coaching; interaction from the teacher, followed/accompanied by reflection in and on action.

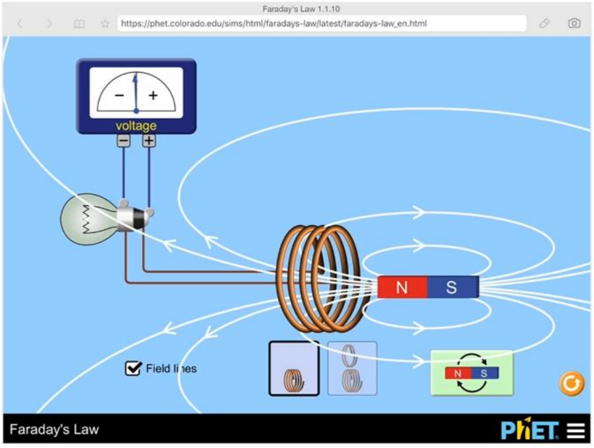


Fig 3.16 Experimenting together with a web browser in the explanation capture software.

Michael discovered that web browsers can be used inside the capture software. He worked on the flux rule using this facility. Manipulating the animation and adding explanatory commentary. He subsequently used this technique in the lessons as did his pupils.

The making of explanations using the capture software and the PhET animation confirmed link 3. Links 1 and 2 are inferred because he has worked on the flux rule with me in coaching and he is trying to assimilate it into his CIA of electromagnetism. A great deal of reflective thought has been required and his personal knowledge domain has be change considerably as a result.

1	In all the coaching phases of the intervention, Michael is using his PSMK to interact with me.
2	Michael certainly develops PPCK after coaching 1 and 2, using the explanation software and data logging in lessons. He has reflected on the VSReflection tasks and although not totally successful, he has made progress with PSMK on flux rule.
3	He uses the script/theory and practical skills learned, from our coaching 1 session in his lesson.
4	He is very affected by the explanation capture software and wants the pupils to use it. Pupils are talking for more of the class time than I have ever seen.
6	Michael used the explanation capture technique to help his working on ideas with pupils.
7	Michael is allowing to pupils to speak for longer and he is asking more exploratory

	questions. He believes in using data and making explanations and is willing to use these techniques in his teaching.

Table 3.4

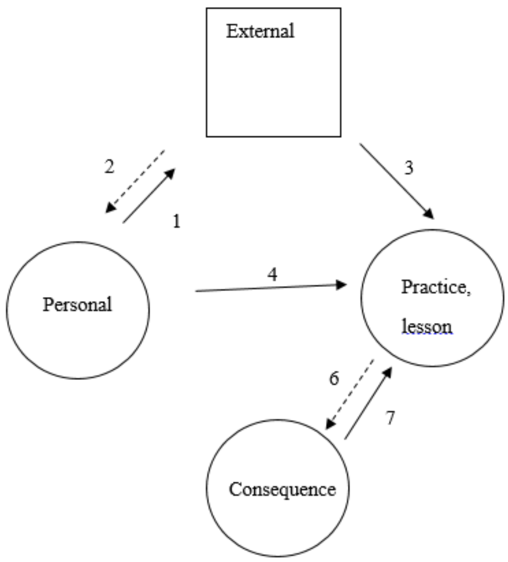


Fig 3.21 IMTPG AR3

T3.4[2+6] Page 46

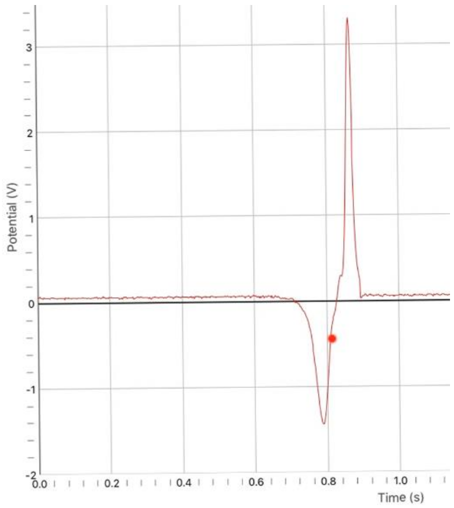


Fig. 3.14 Induced voltage data

He produced data (Fig 3.14) as we did in coaching1 and he engaged the class in talk about the data.

As mentioned before inferring the existence of reflective links is difficult. Link 2, saying that personal knowledge has been changed on reflection on external domain stimulus, is easy in this example because Michael wrestled with the flux rule. Table 3.4[2]

Reflective connection between domains of practice and consequence is fairly easy in this cycle too. I see the fat that he produced data with the class, using methods learned in coaching, then he went on to explain, work on the data, with the class. The class had the opportunity to present their explanations. Michael has definite salient outcomes from this intervention. He has reflected on this and the previous cycles work. The making of explanation using the capture software has become important to him. Link 6 table 3.4.

Appendix 3.J

1. ***Interviewer:*** *We've just collected some data for, right the bottom of the tube. As I predicted, the two peaks are, you got a plus and a minus peak. But they are the same size?*
2. ***Michael:*** *Yes.*
3. ***Interviewer:*** *Now, as you argued, it's falling, so it's accelerating?*
4. ***Michael:*** *Yes.*
5. ***Interviewer:*** *But it clearly isn't accelerating. So, if we think back to mechanics, the thing we were doing three episodes ago. Why might it not be accelerating anymore?*
6. ***Michael:*** *Because it reaches terminal velocity.*
7. ***Interviewer:*** *Right.*
8. ***Michael:*** *Does it reach terminal velocity that quickly? I'm just amazed.*
9. ***Interviewer:*** *It would appear so, in that tube.*

Appendix 3.K

1. **Michael:** *So it's like this effectively, isn't it? So, we are connecting this up certainly. So effectively it just becomes -- So as this passes through, it generates -- we get a potential difference in here, so this becomes the electromagnet. As this pushes down because it is hard to push it through, so that must be repelling so that must be a north.*
2. **Interviewer:** *So what's this end?*
3. **Michael:** *Initially this must be south, now as it falls through well it's going to move to make the direction. So then that's going to become north and that's going to become south. That's the magnet here, is it while it's still inside the coil. I get confused it's a long coil, now.*
4. **Interviewer:** *Well, that will be right but as its coming out-*
5. **Michael:** *Well then the north here. [crosstalk]*
6. **Interviewer:** *No, as it comes out which is the last pole-*
7. **Michael:** *South so it should be attracted to the north.*
8. **Interviewer:** *All right, so hang on let us be careful. So, let us draw the magnet down here.*

We are getting there and need a diagram.

9. **Michael:** *As it come out.*
10. **Interviewer:** *Yes.*
11. **Michael:** *So that should still be south, it's just dropping through here.*
12. **Interviewer:** *And so this north here is the electromagnet?*
13. **Michael:** *Yes.*
14. **Interviewer:** *Okay, so has the current change direction in the coil?*
15. **Michael:** *Initially yes, because it was south and then as it is going through its become north, so that's now going to attract.*

16. **Interviewer:** *That's Lenz's law and that's when you're turning it feels hard to turn when current flows-*
17. **Michael:** *So what is Lenz's law?*

This has been a long story and Michael wants a summary.

18. **Interviewer:** *Lenz's law says that, induction effect will produce magnetic forces which will try and oppose the inducing change. Now, if that happens then you don't get any craziness in the world of energy conservation.*

Appendix 3.L

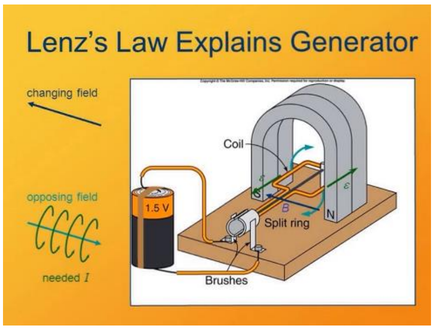


Fig 3.19 Motor

Then he uses a motor, to talk about a generator but not intentionally (to talk about back emf), he does not spot this graphic concerns a motor!

1. **Interviewer:** *Okay, we're looking at the third slide now.*
2. **Michael:** *Yes. This is where I got completely confused.*
3. **Interviewer:** *Okay, let's try and break it down a little bit. So, the picture, the graphic in the middle. What's that showing?*
4. **Michael:** *We have a generator, but we've-*
5. **Interviewer:** *How do you know it's a generator?*
6. **Michael:** *[laughs] I know because we have a coil within a magnet and we have a commutator. If we turn it we should get current generated, but there's no way of turning it in this situation, but that's similar-*

7. ***Michael:*** *-but then if you connected a power supply to it then it would affect this and becomes like a motor rather than a generator.*
8. ***Interviewer:*** *Right. Okay. So, the picture that we've got-*
9. ***Michael:*** *Is a motor.*
10. ***Interviewer:*** *Your reasoning is interesting because what you're saying is that-- or what you're wondering is, what's the difference between a motor and a generator?*
11. ***Michael:*** *It's the same. You have to provide energy in a generator, whereas in the motor obviously, you use an energy source.*
12. ***Interviewer:*** *Okay, now, let's take the battery away and we can put a handle on here and we can literally turn it. Then it's a generator. How does Lenz's Law apply to that?*
13. ***Michael:*** *With the generator, when you turn the handle of the generator, you're moving the coil through the magnetic field which is you are going to have current*
14. *flowing through it and that's going to be opposed by that magnetic field. So, the magnetic field from the current is going to oppose the magnetic field from the bar* ***[unintelligible 00:02:07]*** *magnetic thing in this case and that you going to-- you have to do some work possibly-*

After some confusion with the graphic he produces a reasonable discussion of Lenz's law. Michael used some published resources to help with this explanation task. He did not use then well, but they lead to a good coaching session.

Appendix 3.M

Interviewer: *How have you found our approach to physics teacher education, over the last eight or nine months?*

Michael: *From my own personal point of view I found it incredibly helpful in that as I've been through the process with you, it has—using explanation capture, particularly, has really picked out my misconceptions and the mistakes I was making.*

Michael: *Yes, then I found that it certainly really improved my practice and really improved my understanding of physics, generally, as a topic.*

Interviewer: *Can you try and express how it's been different, what features you've liked or disliked?*

Michael: *I've liked the fact that it's made me think-- before I started teaching, it actually made me think deeply about the topic. Rather than just superficially looking at the specification points, which is kind of possibly what I'd been doing with physics before. Then, not really thinking deeply about what's going on and not really having a full understanding of what I'm teaching sometimes. Then probably passing on misconceptions to students. By reflecting beforehand and really focusing on--*

I think the problem with any of these topics is that you don't actually know what you don't know, if that makes sense.

Michael: *This highlights to you what you don't know. I was confident teaching physics, I think overly confident. I thought I had a better understanding of it than I did and that's potentially a real risk for non-specialists, is they think some of these ideas are quite simple* *and straightforward and actually it's very easy to get it wrong and then pass those misconceptions onto students and this process really highlighted it to me.*

Interviewer: *Okay, again, I think you've touched on this, but I'd like you just to reflect directly on it. Would you say your ideas about what makes good physics teaching have changed and if so, how?*

Michael: *I wouldn't say specifically about-- Well, yes, I think I knew already what was required to be a good physics teacher, I just didn't know that I couldn't do that. You need to have the excellent subject knowledge to teach anything and to really get the idea across, you need to be able to explain it really clearly and really well. That requires really good subject knowledge. Otherwise it ends up being a very superficial explanation and then you just gloss over the bits that you're not clear on.*

Interviewer: *Would you say I was able to show you a few of the tricks of the trade as well with regards to practical approach?*

Michael: *Yes, absolutely. All the stuff where we-- especially when we talked about magnetism, when we were looking at the flux lines and I hadn't really-- I had a vague inkling about what we were talking about. This whole idea of the rate of change of flux and everything juicy. I just didn't know that and I don't think it's even particularly clear when you read the textbooks, it doesn't't--*

Interviewer: *That's very true.*

Michael: *It's when someone actually explains it to you and shows it to you.*

Interviewer: *Yes. Now, we have over, on several occasions, talked about you going forward, are there any of these techniques that you would use in your teaching as you go forward?*

Michael: *Yes, and as I've mentioned before, I've already tried to use the same techniques with different groups as well. I'm not just teaching physics. I generally use it to change my practice and I've used it with all sorts of different ability groups and all sorts of different ages. I think it's always a useful tool to use when there's an abstract concept. I showed you some samples I made. I used it with year seven to try and explain diffusion. I've used it recently with bottom set of year nine to try and explain the circulatory system and looking at how gas exchange occurs in the lung.*

Interviewer: *Yes, well it's a good technique, but there's a lot to be done to develop there.*

Michael: *Yes, there is yes.*

Interviewer: *Okay, the last reflective question. If you had to describe and explain what we've been doing over these last nine months or so, for example, let's say you had to do it with the IOP group of teachers in a meeting, in a nutshell, what would you say?*

Michael: *Okay, I would say that it's a tool that you can use as a teacher to get-- If you use it before the lesson, it allows you to really-- by trying to explain what you are teaching-- the concept, it really makes you think more deeply about what's happening. There are two sides to it. I think as a teacher it really allows you to recognize misconceptions that you have and it allows you to really work through them to a certain extent, especially if you've got support.*

As the students, I think it's been really powerful as a mechanism for feedback so you can-- the fact that students have to explain in detail in the in the video, the concept that you're looking at, means that they have to think very carefully about the language they use. They have to think very carefully about how to express the concept, which I think really helps them to understand it. Equally, as a teacher, it allows you to really pick up their mistakes and their misconceptions.

Again I still would like to look at it, extending the idea, so you can use it to give them more feedback, but I think that, again, that's something for their future and there's also technical issues that seem to be holding on for the minute.

Appendix 4.A

Coaching

In this work shop I will share some of the results from a current action research project. Underpinned by educational research, the workshop will allow you to;

1. Try a technique to encourage reflective practice by “capturing” explanations made by teachers. The method of stimulated recall will be illustrated and its use as a coaching technique for teachers will become apparent.

2. Use wireless data-logging to gather data for discussion and explanation making.

3. The POE method to encourage explanation making will be illustrated.

How can we describe reflection and explanation

I will begin with brief introduction to the ideas of Dewey and Ogborn

How did Dewey define reflection? A Summary of his key conceptions

What according to Ogborn et al. (1996) are the key elements in any scientific explanation?

Some results from action research project, where “captured explanations” are used to encourage reflection and conceptual change in teachers. The technique is facilitated by a peer mentoring/coaching relationship

How do I capture explanations?

A use for wireless data-logging.

POE as useful technique to encourage explanation making

Designing and analysing a mentoring session using the Clark and Hollingsworth "Integrated model for teacher professional development, 2002.

Discussion. How to develop this technique for coaching?

Appendix 4.B

<u>Using "Explanation Capture" and VSR Technique Charterhouse 12/2/18</u>

1. Would you consider using the technique, "explanation capture, VSR"? If so what did you like about it? What problems do you see with using it?
2. If you would not use the technique can you indicate briefly why not?
3. Can you say what you would do with the technique that is different to the examples discussed in the workshop?
4. If you would like to collaborate in its development and have not made contact write contact details here.

	Would you consider using the technique, "explanation capture, VSR"? If so what did you like about it? What problems do you see with using it?	**If you would not use the technique can you indicate briefly why not?**	**Can you say what you would do with the technique that is different to the examples discussed in the workshop?**
1	I like the idea of it-powerful.	The time to develop a safe relationship is an issue. Also colleagues need to be prepared to take a risk.	Might encourage teachers to use this as a form of AfL.
2	I would consider using it but more for coaching/mentoring	I would not use it for students because there are too many	I might use the screen capture myself in a lesson or as a

	rather than in the classroom. It was a great tool for allowing teachers to reflect on their practice in a non-threatening way. It allowed for some very useful “aha” events.	logistical problems. Lack of computer labs in school, students not having access.)	revision tool for students.
3	Yes, nice-real time. Care needed with start and end points.	Blank	Explore ideas/applications
4	Yes_if the nature of the relationship with the mentee and the time available for mentoring lends itself to the process. I can see it being very valuable indeed.	N/A	AT this stage no. I imagine my use of it may develop organically with my experience of using it.
5	I would consider it in the right circumstances. See Q2. To use a cliché, “what’s not to like?” about the process. An excellent and effective insight into the current knowledge and understanding of an area and its development through exploration. I am thinking of use with students as I’m not in a mentoring situation.	You need the technology available to do this with a large group-and the time. What would I not do instead?	I can’t say need time to consider.
6	Yes I would. It draws out ideas, it looks useful. Problems: Time-do we have time to use it appropriately? Tech-can everyone access it?	Blank	Could be used with students as well as teachers. Could be used in lessons-video a small clip and explain what is happening.
7	Possibly not in what I currently do. If I was working 1 to 1 with someone over prolonged time then maybe	Rather time consuming to do it properly, but I like the idea of it.	I can see its merits in mentoring/tutoring A level students.
8	I need to do a trial and find a free long term solution. I feel ,on small classes at KS5 it might be beneficial but time consuming for a set 132 students.	Cost of apps. We have 1500 students and 200 ipads. Any app we buy we must have on all the ipads.	May use the software personally to show students exam techniques or core practical uses/explanations.
9	Potentially. Cost, timing and access are biggest issues for the school and area.	NA	NA
10	Yes, will help with pupil explanation skills. Time is make assessment and feedback is a problem.	Blank.	Set some theory examples-not just practical demos. Get pupils to explain their own ideas of theoretical concepts, Maybe peer eview ideas.

11	I would consider using it with my initial teacher training students. I go to Leicester Uni to deliver subject specialist training twice a year and could set homework in session to be completed 3 months later. Problems: students not doing it.	Blank.	Blank.
12	It is a nice idea but within school there are technological problems that might limit use. I feel that would need some support myself first with the software before I used it with anyone else (colleagues or students)	Blank.	Possibly use with student teachers to demonstrate how they would explain to a class rather than simply explain? Use it to say how would you explain this to a Y7 or Y12 and then compare what you would do differently. Use with SEN students.
13	Yes- for A level classes (small classes) only or for creating revision resources for my students. Problems needing time to get my head around the software- its not that intuitive.	NA	Potentially airdrop etc the videos made by small groups of students to the main board so that the whole class can watch and comment. I have done something similar when explaining stores of energy.
14	Yes definitely. Occasionally both as group tasks and plenaries. Technology issues will make it hard to use regularly.	Participants do not always have devices that are suitable. The schools I am at do not always have reliable devices/wifi.	Possibly provide sample videos.
15	Yes, it would be really brilliant to teach and draw/model graphs. Maybe it might be difficult/take time for students to pick up on how to use it.	Time and cost.	It would be brilliant to use for you tube videos! Educational physics of course!
16	Yes, it is different in terms of forcing the student to be productive. Technical issues-can not IT enabled students access it? Up front set up? Time to review/feedback.	NA	I would possibly use it for a term story arc project. Eg forensics or space shot project.
17	Yes-especially for hearing the explanations thinking through	Blank.	Blank.

	process. The idea it does not need to be completed at a set time and can be sent remotely. Problems-Technology lack of		
18	Yes, since can get students to analyse and visualise tasks for easy assessments.	NA, but cost might be a problem.	Set as homework for A level students.
19	Yes Exposes misconceptions. Provides a good insight into thought process without scaffolding. Issues around handing in/marking. Use of quiet areas for classes.	Blank.	Use with still images as well as videos.
20	Yes, time constraints.	NA	Get them to do one, then self-review and do a second one and discuss progress from both and areas to work on.
21	Possibly with students and coaching. Good points-independent, not led by coach-given a chance for free flow of ideas and insight into the chain of thought. Problems-time consuming, based on availability of software and hardware.	Cost and time implications.	Peer discussions between students, Use as a cascading tool.
22	Yes-depth of understanding of participants thought process.	Struggle to do with students due to time constraints or reviewing.	Use of teacher language. Collaborative working within a department. Sharing strengths in whole dept whole scholl CPD.
23	Yes, I thought it would be a very useful tool. Quite time consuming to look at submissions from a student group or group of teachers. Possible IT problems. I personally am not confident with IT apps.	Blank.	Not able to say really-until I have an opportunity to familiarise myself with the technique.
24	Yes, being able to see the thought process used to explain situations. Willingness of person to use the software.	Blank.	Follow up to CPD for individuals who are finding a certain topic difficult to deliver. To give guidance and correct misconceptions.
25	Yes- like being able to record, annotate and reflect. Data capture enables it to be revisited at later date. Can be a	AS mentioned above, drawbacks are cost and time. I would like to try it but may not be able to fit it in.	Can more info be given on how technique moves on?

	work in progress. Problems of cost for ost schools also seems to be quite tie consuming for both coach and teacher. Is there tie to go back over feedback?		
26	I think it is a good idea to capture live thinking and explanation. Is it time consuming to analyse the video if trying to coach a number of individuals?	Problems of permission for videoing if involving children.	Video of teachers talking to small groups of students or interacting with a whole class especially to deal with questioning techniques.
29	Possibly-I really liked the talking throught thinking, then being able to replay explore misconceptions.	Time to involve lots of people doing it and following up-would use, more likely,	Blank.
28	Yes. I liked effectiveness, Problems cost, time involved in getting set up and getting equipment.	Problems indicated.	Use it for my own personal development also.
29	To promote individuals own learning. Allowing me to set tasks (coaching and mentoring tasks) that then gives someone the time and opportunity to construct a solution. I particularly like the fact that images and voice can be captured as a video file and then reviewed. Accessing some ones thinking is used appropriately would be valuable to watch learning happen. A problem might be that it becomes over critical; think the respondent may be too concerned with being right or wrong and so will overly plan a response.	Blank.	Rather than set tasks which someone responds to allow the end user to use it to pose problems that they illustrate with diagrams, pictures, photos. So the subject actually dictates the content rather than the coach.
30	Yes-its as good idea. Any concern is that perfectionist students would be more worried about the presentation that the physics content.	Blank.	Blank.
31	Yes just like you said, you really get to hear the thinking of your learner and get to the	Blank.	Blank.

	root of misconceptions. Problems: Time. I have very little time and your VSR is certainly not a quick fix.		
32	Probably not.	Time to explain it to teachers, set it up, and analyse it.	Blank.
33	No.	No.	No Sorry.

Appendix 5.A

Interviewer: *We are now recording. Okay. I'm going to ask Lilian and Estelle to begin by, just to summarize in a few words your experience of what we were doing throughout the autumn, on Saturday mornings. What does that mean? It means how you felt it was useful and/or different to other types of knowledge enhancement courses that you've done? Is that a clear enough question? Forgive me, if we begin with Lilian*

Lilian: *My previous experience of knowledge enhancement had been a 12-week SKE, doing chemistry. That was really to get through as much of the A-level syllabus as we could in that time, and just refresh. I've been 18 years out of education and longer for physics. Actually, 21 years. I didn't do it at A-level standards. A long time, and the difference between the SKE and the physics piece is that I'm not a physics specialist. My knowledge of physics is the lowest of all the sciences.*

Here, it was more about what I felt or we made it about getting rid your own misconceptions, making sure you truly understood. It wasn't necessarily about delivering, ticking the box and going, "Have I covered all of this?" It was more about, "Do you understand?" That was really helpful because I don't want to be thinking, "Do I understand?", with every lesson or within the lesson as I'm talking, that's inappropriate. I needed a forum to be able to work on that, for myself.

Interviewer: *That's great. Estelle?*

Estelle: *Interestingly, I wasn't offered SKE before doing the teacher training, though I would have liked to have done one because I've been out of education for a very long time and my biology was shocking. I wasn't offered anything. What I really liked* *about this is there is no silly questions in this room. I really liked the fact even though I've got a Ph.D. in physics I could still put my hand up and go, "Hang on. I've thinking about that wrong the whole time." There was no judgment or anything. I really liked the fact that you could probably work out into your misconceptions and your understanding. It was fine, perfectly safe to do that.*

Interviewer: *Great.*

[00:02:39] [END OF AUDIO]

Interviewer: *All right, my next question, I'll take a bit of time trying to explain it because it's quite a tricky idea to get across. I refer to you guys as the Reading Three, and in my head, when I'm thinking about you; the main idea is that you are a mixed background bunch. No physics experience, well physics experience from school but nothing formal (Lilian), physics PhD (Estelle) and then Dan was somewhere in the middle. That's a very diverse group of people in terms of their physics background.*

Normally, you would divide a group like that and you would treat them as separate entities, but you guys, you jelled and I want to try and explore why that was the case, but you jelled and it was, I thought a very useful forum and very interesting experience. We'll begin with Lilian, what do you think were the advantages of working with these super experts that you had around you in the room?

Lilian: *Working with them as real physicist and teachers of physics, I could figure out how they would do things in the classroom and I could learn from that. I was able to articulate the things that I didn't understand and everyone felt like they were really trying to help. From their backgrounds, et cetera, I just felt like we were a team and what I was contributing was, what the students might contribute and not understand.*

Everyone else was trying to figure out the best way, to help the students understand that ***[unintelligible 00:01:50]*** *students was also me, and then I could project that into the classroom and figure out how-- when I understood, how my students could then be feeling as well.*

Interviewer: *Excellent. Were there any disadvantages? I mean, perhaps, you might have been intimated by Estelle's PhD knowledge in physics?*

Lilian: *I do feel that my subject knowledge is a weakness or at the started this year, I felt that. But you've got two ways of dealing with that, haven't you? You can either, shy away from it and it will continue to be a weakness or you can go, "This is a weakness, I need to do something about it." If that's your stance then you can't go in and just shut your mouth and not understand and not say it.*

I think that's a confidence thing, isn't it? You have to be willing to put yourself out there and fail, but I'd rather fail here than out in the classroom and that fixes your mind, doesn't it?

Interviewer: *Mm-hmm.*

Lilian: *Because if I didn't say here-- what have I got?*

Interviewer: *Absolutely.*

Estelle: *This kind of goes back to **[unintelligible 00:02:54].** Yes, it was absolutely fine to fail here because everyone makes comments that were wrong or they had misconceptions and therefore it was totally safe. In this room, you can talk complete nonsense and its fine.*

Lilian: *It felt like you valued when we said we didn't understand as well though. It was almost-- I almost felt like I was helping when I said it, which helps a lot.*

Interviewer: *I think that's true. That's something I was trying to consciously do with you as-- you guys as a group because I wanted-- as you've said, I wanted people to be honest about what they understood and didn't understand. Putting it out there meant that we could do some useful teaching/coaching. Whereas sometimes in these sort of SKEs, it's about getting through the material, taking notes and ticking the box, but then, I think again, you said this Lilian though, you don't want to be in a classroom with kids and suddenly realise, "I tick the box about Newton's second law, but I haven't got a clue what it means and I don't really understand it. Therefore when difficult questions come up, I'm going to be floundering."*

Lilian: *See that's the difference. No one made us be here. We didn't have to tick any of the boxes, did we?*

Interviewer: *No.*

Lilian: *We chose to come here in our time to try and develop ourselves. And in that context, it's like you've got to pass the SKE or pass the PGCE, you need to pass your own test to be able to talk about it in the classroom and that is different.*

Interviewer: *Let's just come back to Estelle and say, you are working with Lilian, the biologist?*

Estelle: *Well, I'm pretending to be a chemist.*

Interviewer: *Chemist.*

Estelle: *I had half a biology degree, but I'm a chemistry specialist. My SKE changed me.*

Interviewer: *Right, good. Not a physics specialist, but a chemistry-biology specialist. Did you see advantages to working with Lilian?*

Estelle: *Yes, lots of advantages. But firstly because I'd been out of physics, for a long time, 15 years. I felt a huge amount of pressure because everyone, "You got PhD in physics, you must know everything." And I'm like, "Yes" but some of the physics you teach at school, you don't do again at university. It's school physics and the end of school physics so I have not seen that physics for 20 years.*

*Some of **[inaudible 00:05:27],** no we don't. The other thing is, some of the things that-- particularly when we talked about flow, my instinct-- you said I gave a really physics answer. I didn't even realise I'd given a physics answer. I just thought I'd given an answer because to me that was purely-- that's what you did.*

That actually being shown, that actually I still think like a physicist and therefore sometimes I need to think a lot of people won't was incredibly useful because there was a lot of things that I hadn't realised I was automatically doing.

Interviewer: *I think that my impression was that, and I think Lilian said it as well, she was the pupil but she was like the dream pupil. She was the one that was going to not sit there and go, "My god, this is so tricky. I can't. I'm just giving up." She was persistently going, "Oh, I'm not quite clear on that, can we try that a different way, can we look it a different way," and that meant that all of us, in the room could really get down to "brass tacks" in terms of explaining the concepts.*

Estelle: *And then that did expose the fact that actually when we come down to break it down to tiny little steps, I've got gaps, I can do the whole concept but there's little gaps. The other thing that you might not have noticed is that Lilian was giving to be quite a lot help in biology.*

Interviewer: *Was she?*

Estelle: *She was.*

Lilian: *I didn't know [crosstalk].*

Interviewer: *While we were?*

Estelle: *You did every so often; I would ask you a biology question. But often before when we were getting coffee or doing other things I would say, "I'm doing this in biology. I have absolutely no idea," and you would say, "You need to think about this, this and this." And I would then go, I will go home and look that up. You probably didn't even notice.*

Lilian: *I didn't. I absolutely did not.*

Estelle: *While it was a physics course, it was quite useful for me to have access to somebody who knows about biology because I don't. The school is interesting; there is not an equivalent course for biology, for this. For some reason, you see courses like this for physics and they just assume that everyone can do, the biology and they can't. I do not know the biology.*

Interviewer: *That has come up, and it's something worth thinking about.*

Estelle: *I think it helps because it wasn't an expert and a non-expert, we were different experts in different areas of the subject, therefore it wasn't an unbalanced relationship, it was more I could ask you for help with some things and you can ask me for help with some things.*

Interviewer: *That's good.*

[00:08:00] [END OF AUDIO]

Interviewer: *All right, this questions is about the SK experience, in this particular case, in physics that we did here compared to other SK courses that you've done. We'll start with Liz.*

Liz: *There were some differences for me. I felt that the-- There was flexibility in what we were discussing on a weekly basis. The needs of the group, you would flex completely to how quickly we were catching on or whether we needed more time on the ideas. You weren't hung up at all about what we did. Whereas, in other courses where you do have to get through a certain amount of content or whatever, that wouldn't necessarily be the case. I think that the lack of PowerPoint and formalized notes, that goes alongside that, because, if you prepare a PowerPoint, then you're doing that PowerPoint.*

Interviewer: *That's right.*

Liz: *Whereas, if you come prepared to discuss a range of things and then you're flexing it, then there's not going to be a PowerPoint. I would question, in this environment, in that PGCE year, if there had been PowerPoint, would I really have gone back to them? Would I really have gone through the notes? It's more about integrating knowledge into your being, so it comes out what it needs to come out in the classroom rather than going, "I can use that PowerPoint in this lesson," or whatever, because there are other PowerPoints that you can get in your schools.*

That's not the point. The point is, "Can I teach physics in a meaningful way where I understand it and I can help others to understand it?" That needs to be in you rather than through notes or PowerPoint. What else was different--?

Interviewer: *While you're thinking, what about this, Esther--? [crosstalk]*

Esther: *I was actually going to say very, very similar, I am glad there were both notes and PowerPoint, because, one, they would have just got filed in a folder or something else I was supposed to be reading at some point. That's now a big folder. It wasn't about knowledge. We weren't coming out of this with a list of equations in our head or being able to solve exam questions or anything like that. It was about understanding, which is a very, very different way of doing the course.*

Liz: *The lack of home work. It was enough to get here every Saturday on top of everything else. If there had been a, "I've got to do this homework," I think it would have pushed me over the edge and I might not have been able to keep it up. I could keep up that block of time for thinking about physics. That was all I could do. Not having that, "I've got to do something else" was really helpful.*

Interviewer: *That's a good point.*

Esther: *The other thing that-- I haven't done any other courses. I've gone online, the RSC online, Chemistry courses. They're very much on science. Here was very much a mix of science and pedagogy. It wasn't just, "This isn't science, this is-- We're having a physics class." We weren't having a physics class, we were having a teaching physics class, which is different. It concentrated on how you can possibly portray-- Do this to kids, how you could model it and all of that, which I also found very useful.*

Liz: *I will say, if a weakness is in the way the syllabus is or the way the textbooks explain it, you did find areas of fault there, which was helpful to us to know. We need to know what we need to teach, but we also need to know where it falls down or it's not perfect and how we can help that. That's not something that you always get.*

Interviewer: *Good, excellent.*

[00:03:37] [END OF AUDIO]

Interviewer: *One last question then. Did you feel that anything that you were learning here, could be the pedagogy, could be physics ideas, techniques? Did you feel they were ready for use in your teaching practice, immediate application?*

Estelle: *Yes, because, that one lesson of one week. I came back and I told you the next week. You did the predict, observe, explain. I did that, that week.*

Interviewer: *You did that?*

Estelle: *I did. That was immediate that week, I went in the next couple lessons, did it.*

Interviewer: *Is that something that's part of your teaching repertoire?*

Estelle: *Yes, I keep doing the predict, observe, explain.*

Interviewer: *That's good. Lilian?*

Lilian: *I came into this not knowing that physics still goes back to France. I haven't taught all of it yet. I know I've got pictures on my phone and notes that I'm sure I will go back to when I teach for the physics classes. I was just trying to think, there was one thing that I was doing that week and we did in quite a lot of detail. It's that law you gave us, I've forgotten what it was but it did really help.*

Interviewer: *Could it have been the refraction?*

Lilian: *Yes, it probably was the refraction piece. I could ask the right questions to get me ready for that lesson. It depends in which state your classes are at. Whether, what we cover here works immediately, but it will certainly it will certainly come in.*

Interviewer: *Brilliant. Thank you both.*

[00:01:28] [END OF AUDIO]

Appendix 5.B

From: [redacted]

Sent: 15 June 2018 11:23

To: [redacted]

Subject: Thank you

Hi [redacted], here's the first question from the physics paper. It's exactly what we did with year 11 in the lessons you helped me with. We made EE videos to explain this very graph! Hopefully they remembered it!!

Michael

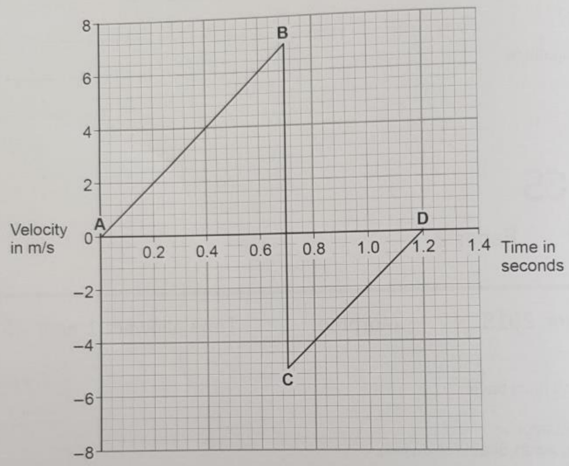
0 1 A child drops a ball.

The ball hits the ground and bounces.

Figure 1 shows the velocity-time graph for the ball from when the ball is dropped until when the ball reaches the top of its first bounce.

Air resistance has been ignored.

Figure 1



0 1 . 1 Describe the motion of the ball between points **A** and **B** on **Figure 1**.

[2 marks]

0 1 . 2 What direction is the ball moving between points **C** and **D** on **Figure 1**?

[1 mark]