# Developing a coaching model for teachers' professional development

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A Research & Development Project
Submitted for the
MSc in Teacher Education 2018

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# Developing a coaching model for teachers' professional development

## 1. Introduction

### 1.1 The rationale for developing a coaching model

The Stimulating Physics Network (SPN) is a government funded programme developed and managed by the Institute of Physics. The programme aims at supporting schools where the teaching and learning of physics are limited by the lack of specialist teachers of physics. This shortage of specialist physics teachers is evidenced by the decline in applications to post graduate certificate of education (PGCE) to teach physics. According to the tes (formerly Times Educational Supplement) the number of applications dropped by 23% in 2016 (Bloom, 2017). Moreover, according to the Independent "more than a third of physics teachers do not hold a degree in the subject" (Pells, 2017). In their recent report on teacher retention Lynch et al. (2016) identify males science teachers with 5 years, or more, teaching experience as the group with the greatest intent to leave teaching (p12). Taking these considerations into account the SPN programme is meant to be bespoke and a discussion with the Head of Science at participating schools is held to agree on the support a Teaching and Learning Coach (TLC) should offer.

As a TLC I am often asked to model lessons and support the teaching and learning of A-level physics (16-18 year old students). This is usually because the teachers working with these groups of students are newly qualified teachers (NQTs) or they may be the only specialist teacher of physics in the science department, so typically they have to bear the responsibility to develop and deliver the A-level curriculum without other specialists to consult within the school. So, this group of teachers often lacks the experience to structure an advanced physics course and to identify learners' common misconceptions. However, this area of the curriculum can often generate lower numbers of teachers' continuous professional development (CPD) hours than preferable according to the key performance indicators (KPIs) of the SPN programme. This is partly due to the lower number of teachers involved in A-level physics education described above, also affected by the lower number of students taking A-level physics courses, as for this age group in the UK science is not a compulsory subject.

I believe it is important that the programme remains as bespoke as possible, because "engagement of coaching assists the translation of training into increased impact on job performance" (Rhodes and Beneicke, 2002, p298), and I want to continue to support A-level teaching and learning in the schools I work with. Therefore, a need to develop a coaching model that remains bespoke, but that has the potential to grow in reach, has shaped the development of this project.
This dissertation outlines the development and implementation of a coaching model featuring the elements described above with two secondary school teachers.

### 1.2 Key questions

My literature review aims at exploring four areas that significantly contributed to the development of my coaching programme and at addressing some of the needs identified by the teachers coached (coachees) during the programme. These four areas are expressed in the literature review as the following questions:

- What elements support successful coaching?
- How can effective reflective practice be fostered?
- What strategies and tools best develop effective questioning in physics teaching and learning?

- How can students' misconceptions be identified and used to develop deeper learning?

The last two questions are specific to the needs identified by my coachees, so it is important to develop a line of enquiry into those areas of learning and teaching.

## 2. Literature review

### 2.1 What elements support successful coaching?

The literature on implementation of CPD programmes suggests that single one-day training workshops are less effective than sustained programmes over time (Cordingley et al., 2015; Miller et al., 2004; Sholomskas et al., 2005), although Cordingley et al. (2015) admit that "some reviews also found that narrowly focussed CPDL of moderate duration (e.g one day in total) can have a considerable and lasting impact on teaching & learning" (p4). However, there is evidence that ongoing coaching programmes often improve the skills of coachees and execution of teaching programmes beyond what can be achieved during initial training (Berliner, 2004; Cordingley et al., 2007; Darling-Hammond et al., 2017; DfE, 2016; Rhodes and Beneicke, 2002; Starkes et al., 1996). Moreover, Aderibigde and Ajasa (2013), in their survey of 240 Nigerian educators, recognise that "there is overwhelming research evidence that peer coaching is useful for academics' training and professional development" (p126).
In Berliner's (2004) review of four teacher development theories the importance of effective coaching was rated second in importance after motivation for developing expertise (p202). Berliner argues that (p202):

> The 5, 7, or more years needed for motivated teachers to acquire expertise might be shortened or be made richer if some coaching and deliberate practice were to take place. Failure to provide these opportunities could restrict what and how much can be learned in the beginning years of learning to teach

In their review of professional development programmes, Cordingley et al. (2007) conclude that the contributions of specialists that yield highest impact in the professional growth of teachers are modelling of new ideas in the classroom, sustained mentoring and coaching and facilitating teachers' collaboration. In his study of 18 trained school counsellors, Veenman (1995) found that developing coaching skills of school counsellors significantly improved their ability to develop 'autonomy', 'purposefulness' and 'trust building' (p426).
The 'Standard for teachers' professional development' (DfE, 2016) states that effective teacher professional development "includes support from someone in a coaching and/or mentoring role to provide modelling and challenge" (p9).
Rhodes and Beneicke (2002) suggest that encouraging teacher collaboration can empower educators and raise their confidence and self-esteem, and that "the engagement of support using coaching, mentoring and networking activities may assist in the transfer of teacher learning to pupil learning" (p302). They also recognise the importance of establishing supportive relationships of trust and mutual respect between coach and coachee to reap the benefits of coaching and mentoring programmes (p302).
Finally, Foltos (2013) argues that 'top-down' approaches to change in teaching and learning practices in schools view educators "like cogs in an assembly line, not partners in efforts to foster innovation" (Kindle location 681). In contrast, a group of coachees from New South Wales (Australia) felt that "professional learning needed to be driven by student and teacher needs, immediately relevant to their classroom problems, reflective, ongoing, and collaborative" (Kindle Locations 706-707). This 'bottom-up' approach resonates with needs identified by other educators across the world and with the findings of the recent report on effective teacher professional development in US (Darling-Hammond et al., 2017), which

identifies content specific and sustained support that offers modelling, coaching, feedback and reflective practice, as demonstrating high impact in teachers' progress (pp5-6).

Although research suggests that there is wide agreement on the benefits of embedding coaching in CPD programmes, there are varying views on what constitutes coaching and how it differs from mentoring. For example, in the US Robbins (1995) defines peer-coaching as:

> a confidential process through which two or more professional colleagues work together to reflect upon current practices; expand, refine and build new skills; share ideas; conduct action research; teach one another, or problem solve within the workplace.

Hargreaves and Dawe (1990) maintain that "coaching is essentially a method of transferring skill and expertise from more experienced and knowledgeable practitioners of such skill to less experienced ones" and that it "depends on the development of strong and trusting collegial relationships" (p230).
In their review of the challenges for managing teacher development in schools Rhodes and Beneicke (2002) list some definitions of coaching and mentoring (p301):

> Coaching is unlocking a person's potential to maximize their own performance. It is helping them to learn rather than teaching them. (Whitmore, 1995)
>
> Coaching is a process that enables learning and development to occur and thus performance to improve. (Parsloe & Wray, 2000)
>
> Coaching is the art of facilitating the performance, learning and development of another. (Downey, 2001)
>
> A mentor is a more experienced individual willing to share their knowledge with someone less experienced in a relationship of mutual trust. A mixture of parent and peer, the mentor's primary function is to be a transitional figure in an individual's development. Mentoring includes coaching, facilitating, counselling and networking. (Clutterbuck, 1991)
>
> Mentoring is a role which includes coaching, but also embraces broader counselling and support, such as career counselling, privileged access to information, etc. (Landsberg, 1996)

Whilst in the Netherlands, Veenman (1995), makes close links between coaching and 'clinical supervision', defined by "Sergiovanni & Starrat (1983) as: 'An in-class-support system designed to deliver ... assistance directly to the teacher ... to bring about changes in classroom operation and teacher behaviour'" (p416). 'Supervision' is a word often associated with negative aspects of teacher performance evaluation and can hinder relationships of trust, so Veenman (1995) is quick to remind his readers that "to coach means to convey teachers from where they are to where they want to be, and is a non-judgemental process" (p417). This perception is shared by Showers (1985) who concludes that "the evaluation of teachers typically implies judgment about the adequacy of the person, whereas coaching implies assistance in a learning process" (p23).
The Centre for the Use of Research and Evidence in Education (CUREE) issued the National Framework for Mentoring and Coaching (CUREE, 2005) where the distinction between coaching and mentoring is describes as (p5):

- Mentoring is a structured process for supporting professional learners through significant career transitions

- Specialist coaching is a structured process for enabling the development of a specific aspect of a professional learner's practice

- Co-coaching (or peer-coaching) is a structured, sustained process between two or more professional learners to enable them to embed new knowledge and skills from specialist sources in day-to-day practice

These three definitions share common elements, in particular their structured nature and the support aimed at teachers' professional development. However, coaching seems to have greater concerns for the specific needs of educators at any stage of their professional growth. In this sense, 'specialist coaching' seems to have the potential to meet the needs identified by Korthagen and Kessels (1999) when they argue that starting teachers "need knowledge that is situation-specific and related to the context in which they meet a problem or develop a need or concern, knowledge that brings their already existing, subjective perception of personally relevant classroom situations one step further" (p7).
Despite the plethora of definitions and distinctions drawn by many regarding coaching, coaches and coachees seem to agree on a number of core elements that lead to effective coaching, according to the research literature (Aderibigde and Ajasa, 2013; Foltos, 2013; Rhodes and Beneicke, 2002; Showers, 1985). For example, Foltos (2013) identifies that most coaches describe the professional relationship with their coachees with the five words "friendly, personalized, manageable, private, and supported" (Kindle Locations 398-399). Aderibigde and Ajasa (2013) support the view that successful coaching can be achieved through collaboration, as well as through relationships of trust and mutual respect. In Showers' (1985) view coaches need to be familiar with the skills and strategies identified by the coachees as areas of interest/need and they also need to have access to the coachees as they develop new skills (this implies availability of time to dedicate to the coaching process). In addition, Showers sees openness between coach and coachee as another important aspect of effective coaching. Rhodes and Beneicke (2002) stress the importance of "a climate of collaboration, respect and mutual trust" (p299).
In summary, successful coaching relationships are developed through mutual respect and trust and by fostering a climate of collaboration where the coachee feels safe to make mistakes, because they know that the observations of their coach are non-judgemental and supportive.

Rhodes and Beneicke (2002) also warn about "the challenges associated with the successful management of these [coaching] mechanisms" (p299), if coaching programmes are to bring forth the benefits described above. One of the barriers to effective coaching identified by the majority of coaches interviewed by Foltos (2013) is time, because teachers are "already working at or near full capacity" (Kindle Location 448). So, if the coachee's institution does not afford them the time to engage in meaningful coaching practices, the benefits of coaching are unlikely to manifest, or last. Showers (1985) recognises the need to train coaches and that coaching skills can be built and learnt. Without expert coaches there is a risk that little will be left to the coachee to do, as Foltos (2013) highlights "effective coaches are careful to monitor how much support they are providing for their peer, because it is easy for a coach to cross the tipping point and take responsibility for the learning away from the peer" (Kindle Locations 488-489). Finally, Lofthouse et al. (2010) argue that "it is naïve to assume that [*coaching*] is easy to achieve in a school context" because "when coaching is established as a means of school improvement, it comes under a managerial culture, characterised by hierarchical relationships and auditing processes" (p10).
In the next section of this literature review I will focus on an important aspect of coaching, i.e. fostering reflective practice.

## 2.2 How can effective reflective practice be fostered?

There seems to be agreement in educational research that effective CPD programmes achieve significant teachers' learning (among other elements) by modelling effective practice and reflection and by supporting educators through coaching and expert support rooted in research-based knowledge and practice (Darling-Hammond et al., 2017; DfE, 2016; Cordingley et al., 2007). For example, the Standards for Teachers' Professional Development in England (DfE, 2016) stress the importance of developing CPD

programmes that are sustained in duration and that afford teachers the chance to experiment, give and receive feedback and reflect upon their practice. These are important factors that the international "umbrella" review on effective professional development commissioned by the Teacher Development Trust (Cordingley et al., 2015) also emphasises, as "in the most effective CPDL, specialists supported teachers by modelling, providing observation and feedback, and coaching" (p7).

Moreover, research on the professional development of teacher educators values modelling and self-study as CPD activities that appear to demonstrate positive impact in the learning journey of teachers and teacher educators (Swennen et al., 2010; Swennen et al., 2008a; Dinkelman, 2003; Loughran, 2007; Loughran, 1995). In their study of the work of three teacher educators' Swennen et al. (2008a) highlight the importance of reflection and modelling of educational theory in practice. Whilst Loughran (2007) recognizes the potential of self-study to "develop a model of critical reflection" (p14).
Dinkelman (2003) also promotes "self-study of teacher education practices as a means and ends tool for promoting reflective teaching" (p7).

In their practical guide for schools Lofthouse et al. (2010) promote "pre- and post-lesson discussions", "coach and coachee undertaking joint lesson planning", "coaches observing lessons" and "using video to record lesson for use in coaching discussion" (p14) as effective means to develop coaching for teaching and learning. It could be argued that these elements foster reflective practice and represent a good selection of CPD activities to support collaboration and self-study.

In order to understand how modelling may be an effective means to support teacher reflective practice two frameworks I used during my R&D project will be explored and these frameworks are - Clarke and Hollingsworth's (2002) model of teacher professional growth (fig1) and the Knowledge Quartet (KQ) (Rowland et al., 2005).

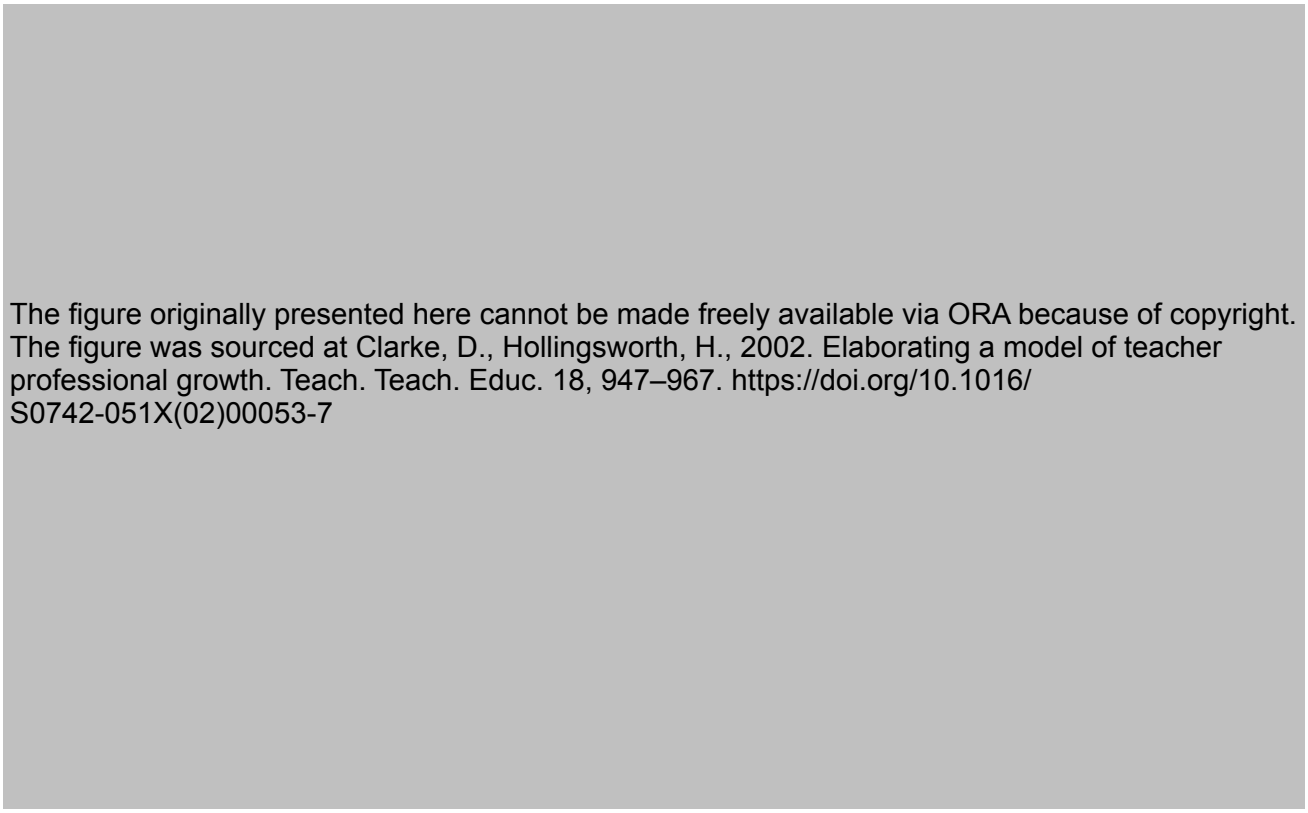



Fig1

The model shown in figure 1 (Clarke and Hollingsworth, 2002) connects the four domains of the "change environment" through a range of enactment and reflection moments. Modelling of good practice in the area under development by the teacher educator would occur in the external domain and through processes of enactment and reflection in the domain of practice by the teacher is

intended to effect a change in the personal domain and ultimately in the domain of consequence where the teachers' practice is developed in the area identified in the modelling. It could, therefore, be concluded that for change to happen and become embedded in the personal domain of an educator, the external stimuli must first pass through the 'filter' of professional experimentation of the teacher and be processed into salient outcomes with the mediation of reflective practice. These salient outcomes will likely produce additional and more committed teacher's experimentation. The resulting salient outcomes are likely to find greater confirmation in the teacher's own practice and will become engrained in the personal beliefs and attitude of the teacher in training. It, therefore, seems reasonable to use effective practice modelling and self-reflection as the "external stimuli" that initiate teacher education learning sequences. It could also be argued that such change in a teacher's personal domain needs sustained duration, modelling of effective practice, feedback and reflection.

The knowledge teachers should develop to help their students to make progress is described by the KQ (Rowland et al., 2005) and it is typified by four "domains/quartets".

- Foundation knowledge; often identified by knowledge of goals and beliefs and by subject matter knowledge (SMK)
- Transformation knowledge; usually associated to pedagogical content knowledge (PCK), e.g. knowledge of impactful teaching strategies and models, as well as knowledge of misconceptions, that allows educators to make SMK more visible and intuitive for students
- Connection knowledge; typically linked to an understanding of connections between different topics and an ability to map complexity, hence to construct effective sequences of learning and teaching
- Contingency knowledge; characterised by teachers' adaptability and ability to respond to unexpected situations during teaching episodes

The elements described in the four quartets of the KQ seem to provide an effective framework for teacher educators to articulate what's needed in developing teaching and learning episodes focused on the progress of students. In light of this analysis, I believe it would be interesting to test the KQ as a tool for coaches modelling self-reflection for their coachees.
In summary, the research literature suggests that modelling, coaching and reflective practice are important activities to facilitate teachers' professional development (Darling-Hammond et al., 2017; DfE, 2016; Cordingley et al., 2007). Also, researchers have articulated some effective strategies and frameworks to develop reflective practice in teacher educators and teachers in training (Swennen et al., 2010; Swennen et al., 2008a; Dinkelman, 2003; Loughran, 2007; Loughran, 1995), e.g. Loughran's (1995) self-study and Clarke and Hollingsworth's (2002) model of teacher professional growth. In addition, although it was not originally developed as a reflective tool, I will use Rowland et al.'s (2005) KQ as a tool to facilitate reflections about observed lessons during coaching discussions and assess its effectiveness in this area. Therefore, a programme of teachers' professional development that seeks to develop coaching activities capable of fostering reflective practice should include modelling of best practice and reflection for coachees, as well as opportunities for coachees for self-reflection and feedback.
In the next section of this literature review I will discuss what strategies and tools best develop effective questioning in physics teaching and learning.

## 2.3 What strategies and tools best develop effective questioning in physics teaching and learning?

Having looked at strategies to develop teachers practice, e.g. coaching, the review now focuses specifically on the areas that this project is seeking to develop, namely teacher questioning.

In his chapter on learning in science Scaife (2008) summarises the findings of Tasker (1981) from a selection of observations of typical science lessons with 11 to 14-year-old children (p90). These observations revealed that often:

- Learners saw lessons as stand-alone episodes, whilst teachers saw the links between them
- The purpose of a task as intended by the teacher is re-interpreted by their students in completely different ways
- Teachers associate a degree of conceptual knowledge of science to their learners that doesn't match reality
- Students' conceptions are different from those of their teachers, e.g. things that teachers believe to be trivial can be seen to have great significance by learners and vice versa

These observations highlight the need to make connections between lessons, topics and different science disciplines explicit for students, to develop greater clarity and effectiveness of instructions and for teachers to identify learners' starting points, as well as to develop a secure understanding of students' misconceptions and strategies to tackle them (Hattie, 2014; Ofsted, 2018; Palmer, 2005). It could be argued that developing effective questioning in the classroom could support teachers in reducing the problems arising from the issues describe above.

The next section will analyse some issues related to students' answers to science questions and will attempt to make some links to the problems described above.

Firstly, when considering questioning for assessment, the following considerations might be significant. Kirschner et al. (2006) observe that "often, students can answer questions in science without truly comprehending any of them" (p9) and that "pupils learn to cope with science language, even if they have not the slightest clue about what it means" (p10). These observations emphasise the importance of asking questions that assess learners' understanding and elicit their alternative conceptions. This element is also highlighted by Chin's (2007) study of 36 lessons of 7 sixth grade science teachers when she reports that "the kinds of questions that teachers ask and the way teachers ask these questions can, to some extent, influence the type of cognitive processes that students engage in as they grapple with the process of constructing scientific knowledge" (pp815-816). Otherwise, "teachers may wrongly assume a level of conceptual knowledge of science in students" (Scaife, 2008, p90) and be unable to "use questioning highly effectively and demonstrate understanding of the ways pupils think about subject content", or to "identify pupils' common misconceptions and act to ensure they are corrected" (Ofsted, 2018, p53). These problems are well synthesised in Black's (2003) warning that "the potential of enhanced classroom assessment to raise standards will never be fully realised unless the regimes of assessment for the purposes of accountability and certification of pupils are radically reformed" (p7). This seems to suggest that teachers (under the pressure of exam results) may favour questions and students' answers that address the expectations of exam boards over the development of deeper knowledge and understanding that goes beyond the 'boundaries' set by the curriculum.

Secondly, teachers who work with students to help them generate their own questions seem to boost learners' motivation. In her analysis of a pupil-activity programme of a 6$^{th}$ grade class Lloyd (1947) used classroom discussion to "evolve" questions under the heading "Questions We Asked" (p24). Through this approach the teacher generates and mediates questions to be used in research projects with the students. These questions are then not just what the "teacher said to" do (p23), but genuine areas of interest for the learners. It could be argued that students become, therefore, more motivated to learn aspects of a subject that are relevant to their interest and context (Palmer, 2005), hence develop enhanced understanding and retention.

Thirdly, good questions need to be supported by effective questioning strategies. Educational research suggests that a significant number of teachers expects students to answer questions no later than one second after asking. If no answer is offered, another question is often asked, or teachers typically answer the question themselves (Rowe, 2003). A likely result of waiting such short time is that the only questions students will be able to answer are those that require very little thought. In other words, this type of teaching encourages memorisation of facts and teachers who adopt this questioning approach are unlikely to be able to move their students beyond "process 1" tasks (which operate automatically, quickly and with little or no effort) and to engage them in "process 2" activities (characterized by mental work that is deliberate, effortful and orderly) (Kahneman, 2011). A strategy to address this issue could be to purposefully increase the 'wait-time' after a question is asked. Black (2003) admits that teachers often find this hard to achieve, because "they had to break their established habits" and the students' "persistence in silence sometimes tested the teacher's resolve" (p10). Other teachers have established classroom norms that support participation and 'wait-time', e.g. "no hands" was described by a teacher as:

> "Unless specifically asked pupils know not to put their hands up if they know the answer to a question. All pupils are expected to be able to answer at any time" (Black, 2003, p10)

These approaches also foster a supporting climate in the classroom where mistakes are celebrated as opportunities for further and collective learning, as articulated by this teacher:

> "Pupils are comfortable with giving a wrong answer. They know that these can be as useful as correct ones. They are happy for other pupils to help explore their wrong answers further" (Black, 2003, p10)

Other strategies to increase participation include 'Think, Pair, Share' where students think about the question asked by the teacher individually, then with their partner in pairs for a further 2-3 minutes and then share their ideas with the class when the teacher asks their contribution. In Black's (2003) study "a consequence of such changes was that teachers learnt more about the pre-knowledge of their pupils, and about any gaps and mis-conceptions in that knowledge, so that their next moves could address the learners' real needs" (p11). These outcomes resonate with Ofsted's (2018) grade descriptors for outstanding quality of teaching, learning and assessment that include (p53):

- Teachers check pupils' understanding systematically and effectively in lessons, offering clearly directed and timely support
- They identify pupils' common misconceptions and act to ensure they are corrected
- They use questioning highly effectively and demonstrate understanding of the ways pupils think about subject content

Moreover, Black's (2003) study matches Hattie's (2014) analysis of over 900 meta-analyses of educational research studies, where he concludes that effective, passionate and established teachers are those who "focus on providing feedback in an appropriate and timely manner to help students to attain the worthwhile goals of the lesson" (Hattie, 2014, Kindle Locations 542-543). Hattie goes on to state that "When people develop new knowledge, they build on and connect it to their previous knowledge or understandings. This highlights the importance of teachers understanding what students already know and can do – because this is the connection for new thinking" (Hattie, 2014, Kindle Locations 2423-2425). It seems reasonable to argue that effective questioning can facilitate these assessment and feedback processes that seek to establish learners' starting points and elicit their misconceptions.
So, the research literature suggests that effective questioning and assessment should help the teacher to identify learners' previous knowledge and understanding and enable them to make informed decisions on teaching and learning sequences that meet the real needs of their students.

In the next section I will explore different types of questioning strategies by teachers reported in the literature and their function and role in facilitating learning. In fact, waiting and inclusive strategies alone are not enough to achieve such goals and a need to refocus teachers' attention on how to design questions capable "to explore and then develop pupils' learning" (Black, 2003, p11) has become evident. A good candidate for this learning exploration seems to be 'socratic questioning' for its potential to encourage learners to "work out each stage of the answer themselves" and for the support it affords teachers to "use a progression of open questions to help students think about any problem logically" and by avoiding "asking any leading questions, offering direct information, or confronting students openly with their ignorance" (Launer, 2017, p783). In addition, Chin (2007) points out that socratic questions "functioned in probing, extending, and elaborating on students' ideas, thereby extracting the information from ''within'' the students" (p824). This approach is in contrast with questioning in 'traditional lessons', whose main purpose is to "evaluate what students know" and where "the teacher asks a closed question that is basically information-seeking, that requires a predetermined short answer, and that is usually pitched at the recall or lower-order cognitive level" (Chin, 2007, p818). On the other hand, in classes focused on learner progress and supported by "constructivist-based instructional approaches" questions are "used to diagnose and extend students' ideas and to scaffold students' thinking" (Chin, 2007, p818). Diagnostic questions, therefore, require longer answers and are generally more open to multiple interpretations and/or articulations, hence engaging learners in higher-order thinking. In this scenario, teachers need to develop greater adaptability and flexibility to respond to students' ideas in a non-judgemental way, as these ideas are likely to expose learners' alternative conceptions and generate moments of contingency that require "contingency knowledge" (Rowland et al., 2005).

In her study, (Chin, 2007) presents three more questioning strategies in addition to "socratic questioning" (described above) – "pumping", "reflective toss" and "constructive challenge" (p823).

In pumping, teachers actively encourage learners to provide more information and they "typically restated the students' answers, and then followed up by posing another question that led to the next step of the thinking process" (p825).

Teachers engaging in "reflective toss" typically answer to learners' comments and questions with further questions aimed at generating "more reflective discourse" (Chin, 2007, p825).

Finally, in "constructive challenge" teachers "posed a question that challenged students' thinking and prompted the students to reflect on and reconsider their answers" (p825).

Chin (2007) concludes that these question strategies "make explicit, the ''what-why-when-which-how'' relationships among the concepts addressed" (p836), hence supporting learners in making connections between and within topics learnt. It could be argued that these techniques can also facilitate classroom discussion, as by encouraging learners to provide more in-depth answers, other students can draw more comparisons with their own responses and conceptions, hence take part in richer learning dialogues.

In contrast, in his experimental study of thirty pre-service teachers, Riley (1986) noted that "Winne (1979), in a descriptive summary of 18 such studies, concluded that student achievement is not affected by level of teacher questioning" (p335). Riley's study concluded that "for achievement of comprehension level objectives, a combination of low and high cognitive level questions with long wait-time appears more effective" (p341). These findings suggest that longer waiting time is an effective tool to support comprehension and cognitive development of learners when coupled with higher level questions, but for "knowledge level objectives" low level questions with wait-times of medium duration may be more effective" (p341).

In summary, students can 'learn' to respond to teachers' questions even when their understanding of scientific language and the questions asked is limited (Wellington and Osborne, 2001). It, therefore, seems necessary to develop classroom strategies that support students' cognitive development and understanding of science, like longer 'wait-time' (Black, 2003) and 'socratic questions' (Chin, 2007; Launer, 2017). However, Riley (1986) stresses the importance to develop both wait-time and high level questioning, because students are likely to be unable to articulate answers to complex questions without

the time to reflect on them and “as wait-time increased from medium to long, achievement scores of students in the low question group declined” (p341).

The effective questioning strategies and foci described above seem to be a promising starting point to elicit students misconception, which is the focus of the next section of this literature review.

2.4 How can students’ misconceptions be identified and used to develop deeper learning?

I will introduce this part of my literature review by analysing some current controversies arising from studies on the “structures that constitute human cognitive architecture” (Kirschner et al., 2006, p75) that have driven Kirschner et al. (2006) to question the efficacy of constructivist approaches to learning and teaching. This analysis will become relevant in my discussion of how learners’ misconceptions can be used to develop new schema and more accurate conceptions (Muller et al., 2008). I begin firstly by considering the literature on working memory and show how this work has not considered the issue that students bring their own conceptions/misconceptions about science from their everyday lives to the classroom. Secondly, I then go on to argue that it is important to use learners’ own misconceptions as a tool for new learning. This became an important aspect of my coaching sessions to model teaching and learning techniques with students in order to support my coachees’ professional growth. Finally, I show some key strategies that have been used to facilitate learning through the use of common misconceptions.

Firstly, in their extensive review of the available research literature on minimal guidance and guided instruction during learning episodes Kirschner et al. (2006) argue that, due to the limitation of working memory, according to Miller (1994) restricted to seven elements, when introducing “new, yet to be learned information” guided instruction is necessary (for example in the form of worked-examples) and preferable to minimal guidance (e.g. inquiry-based instruction), because problem solving “places a huge burden on working memory” (Kirschner et al., 2006, p77). However, Kirschner et al. (2006) highlight that “the limitations of working memory only apply to new, yet to be learned information that has not been stored in long-term memory” and that “when dealing with previously learned information stored in long-term memory, these limitations disappear” (p77). The pedagogical conclusions drawn by the review from these two observations seem to ignore that learners approach new topics, particularly in physics, with their pre-existing 'baggage' of alternative conceptions (Leach and Scott, 2003; Lee and Luft, 2008; Palmer, 2005; Scaife, 2008). So, it seems that learners may have quite a large amount of information (however correct or incorrect) stored in their long-term memory regarding the topic or situation to approach. Therefore, treating these topics as if they were completely new information for the learners might be counterproductive, because the new information introduced, if only presented through highly instructional methods that do not challenge the students’ pre-conceptions, is likely to fail to generate cognitive conflict (Palmer, 2005, p1869; Scaife, 2008, p92), hence convincing learners that a shift in their understanding in needed. This could potentially result in lower retention, understanding and in falling back to previously held and erroneous conceptions when the support system and scaffolding afforded by activities like worked-examples are removed. Muller et al. (2008) seem to argue and demonstrate this effectively in their controlled study of 272 students of physics at an Australian university. In the first group, the students who just watched linear instructional videos containing only correct information retained their own misconceptions and “they became more confident in their preconceptions, believing that the multimedia supported their views” (Muller et al., 2008, p294). However the second group, whose germane cognitive load was raised by presenting and discussing alternative conceptions before presenting a correct explanation, performed better in post-tests and demonstrated cognitive change in interviews. Germane cognitive load is typically linked to the “mental effort used to form schemas and actively integrate new information with prior knowledge” (Muller et al., 2008, p279). It could, therefore, be argued that because the cognitive load of the control group was minimal, these students continued to interpret and process the new information presented to them through the filter of their erroneous alternative conceptions (which were part of their long-term memory). As Muller et al. (2008) found, these “students do not recognize that the presented information differs from their preconceptions”

(p294) and neither can they, because the new information introduced to group 1 through guided instruction, demands minimal cognitive load and will be subject to the "limitations of working memory" (Kirschner et al., 2006, p77). This new information will subsequently be interpreted with the students' alternative conceptions "stored in long-term memory" (Kirschner et al., 2006, p77) and through a range of previous experiences. By Kirschner et al.'s (2006) own reasoning, it should be concluded that the alternative conceptions in learners' long-term memory are the ones that, therefore, remain. In Muller et al.'s (2008) study, however, the students in the second group, who watched videos where alternative conceptions were presented, had to compare their long-term memory conceptions with a range of alternative conceptions and where some did not match their perceived prior experience/understanding this resulted in "students investing more mental effort", so they were "more likely to recognize discrepancies between their extant knowledge and correct scientific conceptions" (p294).

Secondly, having argued that presenting and discussing common misconceptions before introducing new information facilitates conceptual change, I now go on to use the above considerations to develop a rationale for the use of learners' own misconceptions as a tool for new learning.
In fact, Driver (1989) argues that for conceptual change in learners to occur:

> Students first need to be dissatisfied with their existing conception, then for this to be replaced a new conception has to be available that can be understood by the learner and which fits with their experience and is useful in the longer term in interpreting and predicting events (p484)

She also concludes that "the strategies being adopted to promote conceptual change focus on the dissatisfaction criterion by presenting students with new, possibly surprising, experiences" (Driver, 1989, p485). These new and surprising experiences generate the type of cognitive conflicts described by Scaife (2008) when a learner experiences surprising or new situations/ideas. In this scenario Scaife (2008) argues that learners try to interpret the information presented to them using their previous knowledge and understanding, because these students might have developed their own conceptions from experiences drawn from many years of personal interaction with their environment and peers (p93).

These considerations highlight the importance of developing strategies that enable learners to identify the need to question their own conceptions and adapt them where necessary. This is because, although "learners will not stumble upon the formalisms, theories and practices that form the content of science curricula without being introduced to them through teaching" (Scaife, 2008, p121), Scaife goes on to argue that "there is clearly a difference between making the scientific story available on the social plane and having individual students make personal sense of, and become able to use, that story" ( p123). In other words, it seems reasonable to argue that before new and more accurate conceptions and models can be developed by learners, students need to be made aware of the need to develop new conceptions, if we want them to be able to internalise, recall and apply new ideas.

Finally, having argued that simply presenting alternative conceptions to learners might not be enough to convince them that their own interpretations of physics phenomena might be inadequate, this section will review some tools and strategies highlighted by the research literature as effective methods to elicit and tackle learners' misconceptions.

In their review of 'refutation text' research literature Guzzetti et al. (1993) evidence the need to explain why students' alternative conceptions are not adequate, as opposed to simply present alternative conceptions. This suggests that text that includes learners' alternative conceptions and explains their inadequacy is more effective than more traditional instructional text (that doesn't contain alternative conceptions) in generating conceptual change. 'Concept cartoons' (Naylor, 2014) are a type of refutation text that have had significant influence in the science education landscape, although they differ from more traditional refutation texts, because with concept cartoons the refutation is usually left to the learners and it is conducted as group and/or classroom dialogue, with the teacher as facilitator (Dabell,

2008; Naylor, 2014; Webb et al., 2008; Welsh Government, 2010). In concept cartoons, a scientific problem/situation is represented in the centre of the page and a number of characters discuss their views about the problem through callouts (like in a comic strip). Typically, one character will offer the correct explanation and the others will present alternative conceptions. The students discuss the validity of each statement in groups or as a class. In the small study by Webb et al. (2008) in two South African 6th grade classes the authors concluded that "there is promise in using concept cartoons in our science classrooms to provoke argumentation and to stimulate learners' thinking" (p15).

In their study with 54 undergraduate students of various backgrounds Cox et al. (1999) compared the effectiveness of 'vicarious' learning for students watching a dialogue (DL group) between a student and their tutor, with a group of students watching an expert who "verbalized instructional discourse" (DI group) on the same topic (p431). Vicarious learning is understood as learning by viewing recordings of other students having a dialogue with an experienced tutor. Contrary to what Kirschner et al. (2006) might argue, Cox et al.'s (1999) findings from the DL group showed that "the effort of comprehending dialogue, with all its meta-linguistic 'baggage' (compared to expository instructional discourse) does not override its educational utility", because "the dialogue condition was as effective as the expository discourse condition" (p449).
Muller et al.'s (2008) work builds on Cox et al.'s (1999) findings and concludes that linear multimedia educational resources (especially in science) need to include alternative conceptions and their discussion, because the students who watched multimedia resources that did not include misconceptions showed that "their responses to multiple-choice questions and discussions in interview indicate that they generally did not change their previous conceptions" (Muller et al., 2008, p294).
A conclusion that could be drawn from the research presented above is that merely being aware of learners' misconceptions, or presenting these misconceptions to learners is not enough to generate conceptual change, because discussing misconceptions and comparing them to more accurate conceptual models and explanations facilitates the development of deeper learning.

In summary, students approach new physics topics with a range of alternative conceptions built from their personal experiences and interactions with their environment and peers (Leach and Scott, 2003; Lee and Luft, 2008; Palmer, 2005; Scaife, 2008). So, it is reasonable to argue that their long-term memory will contain quite a lot of information (likely in the form of alternative conceptions) about any 'new' topic their teachers will introduce to them. Therefore, it seems simplistic to postulate that guided instruction is the only form of learning that mirrors the human cognitive architecture, as Kirschner et al. (2006, p76) argue. Since "the limitations of working memory only apply to new, yet to be learned information that has not been stored in long-term memory" and that "when dealing with previously learned information stored in long-term memory, these limitations disappear" (Kirschner et al., 2006, p77), it could be reasoned that the misconceptions embedded in the students' long-term memory will prevail and that guided instruction on its own might not be enough to achieve deep learning and conceptual change (Muller et al., 2008).
The use of learners' misconceptions and their discussion is favoured by Muller et al. (2008) as a tool to raise the germane cognitive load of students and generate conceptual change. In a similar way refutation text (Guzzetti et al., 1993) and concept cartoons (Naylor, 2014; Webb et al., 2008) seek to challenge learners' misconceptions by presenting common alternative conceptions to them and by discussing why they are inadequate.
I my R&D study I will seek to adopt these approaches to model effective practice in eliciting and challenging students' misconceptions.

## 3. Methodology

### 3.1 The nature of the intervention and its rationale

As mentioned in the introduction, the need to develop a coaching model that supports reflective practice and has the potential to generate sufficiently high numbers of CPD hours arose from the nature of the Stimulating Physics Network (SPN) programme managed by the IOP. In my intervention I tested a coaching programme which sought to develop teachers' practice in an area of their choice and that might accommodate the limitations of time and the restrictions imposed by the KPIs of the SPN project. The time I have available to work with schools is limited to roughly six sessions per year of 1.5 hours each, but within this time allocation a Teaching and Learning Coach (TLC) like me ought to maximise the number of CPD hours generated in each session, as that is an element by which the national reach and outcomes of the SPN programme are judged centrally and by the Department for Education (DfE). As a result TLCs are encouraged to run workshops with whole science departments and include as many teachers in their sessions as possible. In my professional experience, this poses a series of potential problems for a programme that is meant to be bespoke and that is based on coaching:

- If interventions are run with large numbers of teachers, it is often difficult to cater for the needs of individual teachers
- The bespoke nature of the programme could be diluted in trying to address wider teaching and learning issues in physics rather than supporting individual teachers with interventions that are "situation-specific and related to the context in which they meet a problem or develop a need or concern" (Korthagen and Kessels, 1999)
- Non-specialist teachers of physics who attend TLCs' workshops usually need considerable support in developing a deeper understanding of physics concepts and they often hold the same misconceptions their students show. However, they are reluctant to expose their lack of knowledge and understanding in front of their line managers, who are also attending the meetings. In these settings the coaching dialogue could be choked by the barriers identified by Lofthouse et al. (2010) – "when coaching is established as a means of school improvement, it comes under a managerial culture, characterised by hierarchical relationships and auditing processes" (p10)

My coaching model seeks to circumnavigate these limitations by developing one-to-one coaching relationships with individual teachers (coachees) over three sessions of 1.5 hours and then engage a wider group of teachers in a fourth session where a coachee shares their professional learning journey. In this programme of support the bespoke nature of the SPN project and its coaching focus are fostered by the one-to-one interventions, whilst the higher number of CPD hours demanded by the project's KPIs could be generated by the sharing workshop.

### 3.2 The coaching model

My coaching model is composed of four main phases:

1. Modelling a lesson where the coachee observes the coach teach their class with a focus identified by the coachee based on their individual CPD needs and interests. The model lesson is followed by a reflection and feedback session, where the KQ (Rowland et al., 2005) is used to reflect on the outcomes of the lesson. This also models how the coach reflects on their own lesson and the strategies they employed to facilitate learners' progress
2. The following lesson is team planned and team taught by the coach and coachee. A lesson observation is jointly completed and a discussion of the outcomes of the lesson is carried out in the post-lesson reflection session
3. The coach observes the coachee who has planned a new lesson independently. Observation notes are then discussed in a feedback and reflection session. Typically, the coach will ask

questions they might have written during the lesson observation to help clarify some of the choices made by the teacher. This is done in a non-judgemental way and the nature of the questions are meant to help the teacher to reflect on their practice and focus on students' outcomes

4. The teachers who were coached through this model share their learning journey with other colleagues in their department and/or at regional workshops funded by the SPN

A key learning point for the teachers coached through this model is phase 4, where they have to articulate what specific elements of the programme supported their progress as educators. My aim in doing this is that this particular process will engage them in deeper reflective practice and generate powerful salient outcomes, which will lead to further professional experimentation, which in turn will have a higher potential to become embedded in the teachers' personal domain (Clarke and Hollingsworth, 2002). This final phase is the culmination of the coaching model proposed, because the professional learning sequence converges to the sharing of skills learnt and experienced through a sharing workshop. This resonates with the definition of 'Peer Networking' offered by Rhodes and Beneicke (2002); "Peer-networking may be taken as a generic term to encompass two or more individuals working together to enhance information exchange, dissemination of good practices, and the organisation of mutual support and learning. Such networking may occur between individuals or groups within individual schools or in collaboration with other schools" (p301). In light of these considerations, I am aiming, through this R&D project, to research the potential of the coaching model to support professional dialogue and growth beyond the individual coachees taking part in the coaching sessions.

My coaching model draws its main elements from a range of features common to effective continuous professional development and learning (CPDL) programmes (Cordingley et al., 2007; Darling-Hammond et al., 2017; DfE, 2016). These features can be summarized as:

- Modelling best practice through active learning – this is highly effective when teachers participate in learning activities that they can later use with their students, because they have an opportunity to discuss their learners' alternative conceptions. It is also effective when teachers observe a coach/mentor teach a model lesson with their students, as they can see how effective learning and teaching strategies through their own (or non-specialist) subject can be implemented

- Content focused – the above is usually more effective when teachers experience new techniques and learning activities through subject specific content focus, as this helps them to better articulate and visualise how to transfer these skills

- Using misconceptions to generate discussion and debate in the classroom – I have experienced high impact and learners' progress when students (and teachers) are presented with alternative conceptions, or discuss their own misconceptions, before giving a more suitable explanation/model. This is in line with the work of Muller et al. (2008) described in the literature review.

- Opportunities for feedback and reflective practice – this is key to internalising new strategies and learning. Having an opportunity to discuss a lesson and reflect (ideally with a coach) on each other's practice can generate rich professional dialogue. These reflections are an important component of Clarke and Hollingsworth's (2002) model for teachers' professional growth, as a salient outcome can be reflected upon and encourage a teacher to go further through professional experimentation in their classroom. This experimentation with learners can often lead to further and more evident salient outcomes, as (in my professional experience) it seems much more convincing for a teacher to observe progress in their learners, rather than simply experiencing what seems to be a

good idea during a professional development course. The impact on learners from these salient outcomes will contribute to embed these new practices in the teacher's personal domain through a change in beliefs and practice

## 3.3 The research methods

The key research question which informed the project was:

> In what ways and to what extent does an intervention using coaching to facilitate teachers' professional growth in an area of their choice promote teachers' learning?

Due to the nature of my coaching relationship with the two teachers involved in my R&D project and the time limitations imposed upon us by the SPN programme and that naturally occur in schools, I judged that the most appropriate research strategy to employ was case study, with the case or unit of analysis being the two cases of my coaching interactions with my coachees and their professional growth as a result of these interventions. I favoured case study as a research method because the core purpose of case studies is "to help us notice and understand particular aspects of the human experience that are often overlooked or unexamined by other types of research" (Tobin, 2012, p772). Therefore, the data sources I collected are such that will hopefully facilitate rich descriptions that enable "an in-depth or sharpened understanding of the case" (p772).

In this section I will try to describe and justify the data collection methods I used to answer my research question and to build a picture of my coachees' learning journey over the course of the coaching relationship. It should be noted that the strategies employed to develop my coachees' practice often merged with the data collection methods used.

### 3.3.1 Video evidence

In order to see how the coaching sessions, team teaching and modeling facilitated the teachers' professional growth it was essential to observe the teacher's practice and see the ways and extent these strategies had developed practice. Therefore, videos of each lesson modelled by me and of each lesson led by the coachees were recorded and are available upon request, as for data protection reasons it was not possible to store these files on online platforms. I planned to use these videos to facilitate post-lesson observation reflection and feedback interviews, but this proved challenging due to the limited time available to the coachees for such sessions. So, I reasoned that semi-structured interviews that aimed at clarifying and expanding on the teaching and learning episodes witnessed in the model lessons and coachees' lesson observations would be a more efficient tool to achieve the same result. In other words, the videos have proven to be a useful resource to write this dissertation and represent a portion of the data collected, but have not contributed significantly to the coaching discourse during my R&D project, hence to the strategies employed in supporting professional learning.

### 3.3.2 Lesson observations

The lesson observations served both as a strategy to facilitate professional growth and as a data collection method to answer my research question. In terms of a strategy to develop the coachee's practice both coachees were encouraged to take notes during their observation of my model lesson and I adopted a lesson observation proforma (Appendix 1) to observe their teaching.
This proforma contained three columns:

1. Lesson narrative – an objective account of the lesson episodes as they unfolded

2. Observations, thoughts and comments – observations/comments recorded by the coach as the lesson was observed

3. Review and post-observation questions – mainly clarifying questions that were later used to inform the post-observation interview

It was important for the coachees to focus on the actual events of the lesson, rather than restricting the focus of the observations to pre-determined points, with a higher potential to introduce bias. This strategy fostered dialogue between coach and coachee offering a clear focus on what happened in the lesson (Metcalfe, 1999).
In research terms and to address my research question I adopted classroom observations because they "can allow researchers to understand much more about what goes on in complex real-world situations than they can ever discover simply by asking questions of those who experience them…, and by looking at what is said about them in questionnaires and interviews" (Birmingham and Wilkinson, 2003, p117). In addition, (O'Sullivan, 2006) argues that lesson observations "are critical methods in the effective measurement of quality in teaching and learning" (p252).

### 3.3.3 Semi-structured Interviews

These were conducted with each coachee after a lesson observation. I used 'cognitive interview' principles (Desimone and Le Floch, 2006) in an attempt to take more active roles in the interviews and to avoid leading questions. As mentioned above, these interviews were conducted in most cases straight after a lesson observation, although due to the coachees' timetable this was not always possible. The immediacy of these reflection and feedback sessions proved to be useful in fostering the coach-coachee dialogue, because the events of the lessons were fresh in both the coach and coachee's minds, hence more readily available for recall and processing. I believe this aspect made the use of semi-structured interviews to frame the coaching dialogue more effective than using video clips at a later stage. I also believe that the questions asked supported the development of reflective practice, as they were generated from learning and teaching episodes observed in the lesson. The above focus highlights how interviews were used as a CPD strategy and the below illustrates how the coachees' responses also served as data to inform the conclusions drawn in this dissertation.
I initially audio recorded the interviews with my coachees, but I later discovered that the file format saved by the audio recorder given to me by the university was not compatible with my computer, so I was unable to listen back to these conversations. However, I was satisfied that I had typed the coachees' answers in my lesson observation framework accurately enough to build useful learning profiles from the lessons observed. Moreover, after typing each answer I would ask the coachee to read what I had written and check that it was an accurate account of their thinking.
The choice of conducting post-observation interviews with coachees seems to be justified when considering that "it has been said that while other instruments focus on the surface elements of what is happening, interviews give the researcher more of an insight into the meaning and significance of what is happening" (Birmingham and Wilkinson, 2003, p44).

### 3.3.4 Model lessons

I modelled a whole lesson for each of my coachees' classes and used the KQ (Rowland et al., 2005) retrospectively after the lessons to reflect on my own teaching. Then, I used the KQ to model my reflections of the lessons with my coachees as part of our reflection on the model lesson each observed. Although the KQ was not designed as a reflective tool (Rowland et al., 2005), it also proved useful in focusing my analysis of the model lessons I taught on important aspects of learning and teaching that supported students' progress. This was part of my coaching strategy, but the reflections of my coachees will also inform the analysis of their professional journey, hence represent data collected for the purposes of this study.

### 3.3.5 Co-planning and co-teaching

As part of my development strategy, the second phase of my coaching model involved the coach and coachee plan and teach a lesson together (ideally the lesson following my model lesson). Although a formal lesson plan was not used, the coachees and I consulted each other about the content, resources and sequences to include in the lesson. This was often done via email communication, due to the limited time available and the coachees' busy school schedule. Similar to other evidence collected the reflections of the coachees from these sessions will be part of the data collected for this study.

### 3.3.6 Analysis of data

All these tools were employed in an attempt to enrich the coaching dialogue and facilitate the professional growth of the teachers participating in my R&D project and were used directly with the coachees. However, they also served as data to build the professional journey profiles discussed in the findings of this study. The nature of the data collected is qualitative and suitable for designing the case studies reported in this dissertation.
In addition, Clarke and Hollingsworth's (2002) model of teacher professional growth will be used in this dissertation to exemplify and articulate some professional learning outcomes of the two coachees. This will support the arguments I am seeking to build rather than impacting the coachees' learning directly.

## 3.4 Background and context of the participants

The original project included a third teacher, but for personal reasons she had to withdraw her participation, so I decided to exclude any evidence collected from this participant from this study for ethical reasons.
The two teachers who participated to the whole programme of support are both specialist physics teachers with four years of teaching experience (at the time of the study) in Gloucestershire. Although both teach to A-level (16-18 year olds), their school context is quite different.

Jess (pseudonym) teaches in a girls grammar school where expectations are high and students' results are above the national average, whilst Jamie (pseudonym) works in a mixed gender comprehensive faith school where students typically perform at the national average. Both teachers hold a Physics Bachelor Degree and this is their first job in a school, so they have only worked in one school.
Another aspect in which Jess and Jamie differ is that Jess had worked alongside a more experienced teacher of physics since she started to teach A-level classes, whilst Jamie taught his A-level classes since his first year of teaching without another physics specialist in his science department. Only recently another physics teacher has joined the school and the A-level physics course is now shared between them.
My coaching programme offered support for both teachers with their A-level teaching and, although such a focus was chosen by each coachee and not by myself, this should enable me to make more meaningful comparisons between the two participants and their progress. Within A-level teaching Jamie decided to focus on improving his questioning and in particular to develop richer discussions in the classroom. Whilst Jess was interested in exploring ways to introduce new equations to her students.

I believe my role as TLC placed me in the position of 'specialist coach' described by (CUREE, 2005) in the coaching relationship established with my coachees. In fact, the activities carried out in my coaching interactions are well summarized by figure 2 (CUREE, 2005, p5).

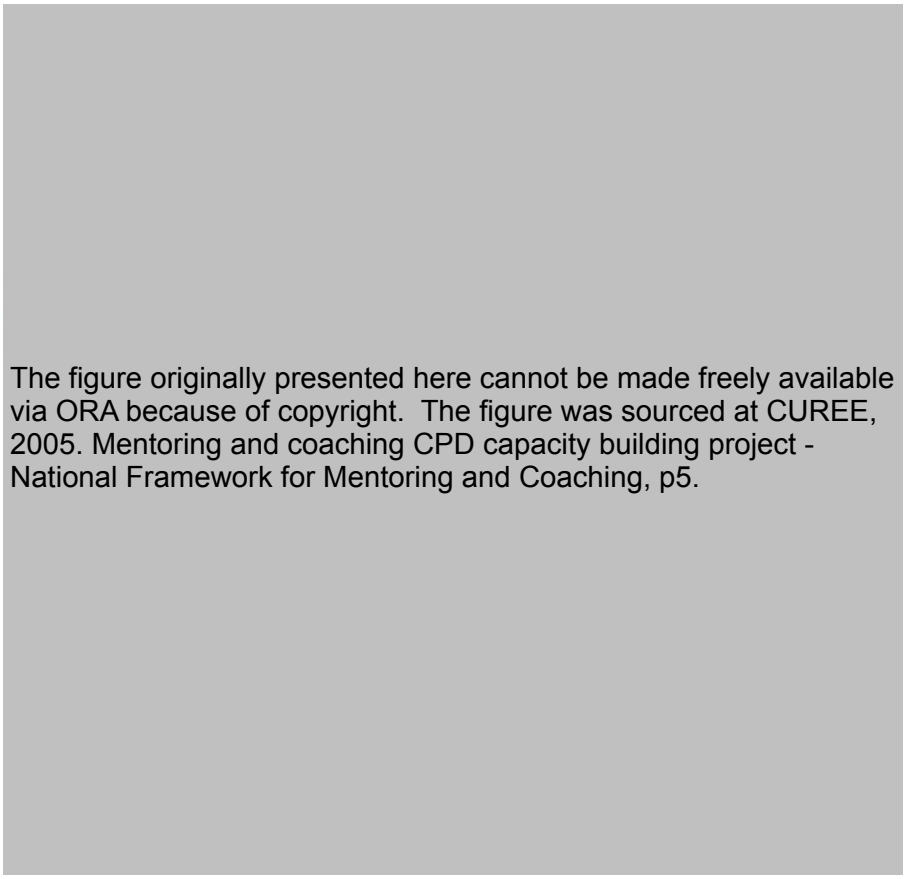



Fig2

3.5 Ethical considerations

The nature of the programme and data collected posed a series of ethical issues that needed to be addressed carefully and to the satisfaction of all participants.
Firstly, I took ethical considerations (BERA, 2011) into account in assessing my role of TLC in Jess and Jamie's schools and I was satisfied that such role does not bear any influence in the performance management procedures and outcomes for these teachers. To avoid feelings of coercion, clear assurances that participation was voluntary and that non-participation was perfectly acceptable were given. The aims and purposes of this R&D project were fully disclosed and discussed with Jamie and Jess and they were satisfied that any data resulting from this project would not be shared with third parties and that anonymity and confidentiality would be maintained throughout the project and beyond. A written and signed consent form was collected from Jamie, Jess and their Headteachers, as well as from other participants who would give inputs into this study, e.g. other TLCs participating to anonymous surveys. These consent forms explained clearly the scope of the project, what data would be collected and in what format, and were approved by the Central University Research Ethics Committee (CUREC – example in Appendix 2). By signing the CUREC consent forms both participants expressed their permission to publish the findings of this study for the scope of my R&D dissertation (Cohen, 2011).
Since video recordings of the teachers were taken, I was careful to renew their oral consent to being filmed before each session, regardless of their signed consent forms, because I wanted to ensure my coachees felt comfortable before each observation and minimise any potential sources of distress that could affect their performance. We agreed to only film myself or the teachers and not to include the faces of the students in any video material, so when a student was called on the board to contribute to a learning point, I would switch off the camera to avoid students being recognised from any of the data collected.
I believe the steps taken to ensure confidentiality, anonymity and that other ethical considerations were carefully approached and satisfied, were sufficient to satisfy CUREC's requirements and safeguard all the participants to this study.

## 4. The findings of this study

In this section I will present the two case studies of Jamie and Jess separately and then I will seek to draw comparisons between the ways and extent the intervention developed their individual learning focus and thus address my key research question:

> In what ways and to what extent does an intervention using coaching to facilitate teachers' professional growth in an area of their choice promote teachers' learning?

The narrative of these studies will be chronological and I will seek to make links to the literature review where appropriate and relevant to the discussion. However, it will not be possible to include a detailed narration of every event that occurred in my interventions, so the main and most relevant episodes will be developed. Each of the four sessions in the coachees' interventions will be presented separately for ease of readability. However, since phase 4 (the regional sharing workshop) was conducted with both teachers present, I will discuss that session separately.

### 4.1 Jamie's intervention

#### 4.1.1 Model lesson

Jamie's learning focus was effective questioning and how to generate richer classroom discussions in A-level physics, and the topic of the model lesson I taught in Jamie's class was an introduction to wave interference. So, I decided to develop activities that would offer opportunities to model the use of diagnostic questioning and effective class discussion strategies, e.g. "pumping", "reflective toss" and "constructive challenge" (Chin, 2007, p823).

Jamie was teaching straight after this lesson, so it was not possible to conduct a feedback and reflection session until the following day. In fact, we had to combine the reflection session for this model lesson with the post-observation interview after the team-taught lesson (phase 2). Therefore, there might be some overlapping in some of Jamie's comments that were relevant and addressed issues arising from both sessions.

Due to my lack of previous knowledge of this group of students I developed a short online diagnostic quiz to establish the learners' starting points on the topic of waves. The results of the quiz revealed that the students' knowledge and understanding of how waves propagate was inadequate in a significant number of students. Although recapping these concepts would be time consuming and could have resulted in not completing all the activities planned, I resisted the temptation to continue the lesson ignoring the feedback from the diagnostic quiz, because doing so would go against "practicing what I preach" (Loughran, 1995; Swennen et al., 2008). Therefore, I showed the students' responses from the quiz and asked probing questions to elicit explanations for the correct answers from the learners. Afterwards, when discussing the lesson and reflecting on this episode of contingency (Rowland et al., 2005) Jamie realised he doesn't always diagnose students' understanding of previous lessons and he could see the value in using learners' answers to recall and diagnose previous learning.

In another part of the lesson I tried to generate rich classroom discussions by means of question and answer (Q&A) sessions. For example, an effective question to open classroom dialogue on diffraction of waves was "Explain why we get a shadow behind a window and why we can hear the doctor calling when we are behind the door in the waiting room". I chose questions like this one in an attempt to deliberately engineer contingency episodes (Hurst, 2017) and to use "constructive challenge", as this question "challenged students' thinking and prompted the students to reflect on and reconsider their answers" (Chin, 2007, p825). This is because questions like this one have a higher potential for eliciting students' misconceptions and unexpected responses, as they require scientific explanations of phenomena not often found in the contexts used in exam-style questions, but that tap into learners' every day experience (a context usually more affected by students' alternative conceptions). In my professional role I often witness teachers who quickly shift the question to pupils who have a higher probability of

giving a good answer, or who perhaps feel more comfortable in taking part to Q&A sessions (especially during lessons observed by other educators), if the student they questioned first cannot offer an answer within an often inadequately short time (Black, 2003, p10). So, I purposefully decided to 'stick' with the first student I called until they could offer a useful contribution for our class discussion. In this process I would reword my questions, or bring the students' attention to simpler analogies and similar situations until the learner was able to construct a more effective model for themselves and that was accurate enough to support the understanding of other students and our classroom dialogue – an example of "pumping" (Chin, 2007). Anticipating and responding to students' misconceptions in this way requires good command of subject matter knowledge (SMK) and pedagogical content knowledge (PCK) (Lee and Luft, 2008), an aspect also highlighted by Hurst (2017) "a deeper level of knowledge to enable a teacher to respond better and to plan and anticipate contingent moments" (p107).
In the reflection and feedback session after my model lesson Jamie commented (when reflecting on my approach to students' answers):

> What I did take from yesterday is that "I don't know" or no answer is not good enough and that I need to get a deeper answer from them, either by answering more questions or wording the question in another way.

In sessions 2 and 3 I could observe a commitment to this approach in Jamie's practice and this "professional experimentation" on his part also generated further "salient outcomes" as a result of the progress shown by his learners (Clarke and Hollingsworth, 2002).
After the model lesson I completed an adapted KQ (Rowland et al., 2005) to analyse my lesson and then shared this by articulating my reflections with Jamie in a post-observation feedback session. Both the adapted KQ and my own analysis can be found in Appendix 3.
This enacted reflection with Jamie enabled me to focus on important aspects of the lesson as well as to introduce theoretical models like the QK (Rowland et al., 2005) to my coachee. For example, when discussing "knowledge of teaching" I wrote on my KQ:

> Q&A sessions used effective techniques, e.g. bouncing the question to different students after an answer was offered to check understanding and encourage discussion. Students were chosen by the teacher, rather than picking learners with hands up.

This offered an opportunity not only to justify my approach to question and answer sessions, but to mention educational research around questioning like Black (2003) and Chin (2007), and reflect on how I applied theory to practice. Another observation recorded on my KQ was:

> Often I asked students further questions in response to their answers to elicit their K&U and help them reach good explanations on their own, instead of offering the correct answer myself

This enabled me to recall and reflect with Jamie on how I used "socratic questioning" (Chin, 2007; Launer, 2017) and "tossing" (Chin, 2004) in the lesson, which became a source of discussion relevant to the focus he had identified for my coaching intervention. This approach not only mirrored Korthagen and Kessels (1999) approach of supporting teachers with "knowledge that is situation-specific and related to the context in which they [teachers] meet a problem or develop a need or concern" (p7), but was grounded in other elements recognised by research literature on effective CPD (Cordingley et al., 2015, 2007; Darling-Hammond et al., 2017; DfE, 2016), i.e. that CPD activities should contain modelling of good practice, feedback and reflective practice with the assistance of expert coaches, be subject specific and of sustained duration.
Modelling reflective practice in this way was beneficial for Jamie, because "thinking like a teacher involves developing a sensitive awareness of one's actions and a consistent focus on recognizing alternative perspectives and approaches to learning situations" (Crowe and Berry, 2007, p32). An

indication that this process was useful in Jamie's professional thinking growth came from his comment that "every teacher needs to self-analyse, but analysing a lesson with another teacher gives a wider view of what happened and how to improve it".
My observations of Jamie's lessons after my model lesson demonstrated that these approaches were experimented by him and eventually led to professional growth (Clarke and Hollingsworth, 2002), as will be discussed below.

4.1.2 Team-lesson

The model lesson showed Jaime's thinking about richer questioning developing in a number of areas. The second phase of the coaching intervention was to co-plan and team-teach the next lesson to see how this learning would be put into practice. In this session the coachee observed me teach a small part of the lesson and he taught the rest of the lesson. I then completed a lesson observation framework to use in our post-observation reflection and feedback session.

The focus of this lesson was Young's double slit interference patterns and Jamie started by recapping concepts from the previous lesson by asking different students to give contributions. He called students by name, rather than allowing hands up and he 'bounced' each question to different students after an answer was given to compare understanding and achieve greater accuracy. When I asked him why he chose not to allow hands up and bounce the question, Jamie replied that:

> It seems to make everyone focus on each question and make them listen to each other more

He then added:

> This way I can make sure everyone answers a questions and differentiate the questions to suit each student

Jamie also reflected on the difference he noticed when using this strategy with different age groups:

> I have used this more in KS4 yr10 and 11, but I have seen other teachers use this even lower than that. I feel like it works best with the older students, as younger students would just go "I don't know" or "I agree"

In this analysis Jamie recognised some of the difficulties identified by Black (2003) who commented that students' "persistence in silence sometimes tested the teacher's resolve" (p10).
In reflecting on what he learnt from the model lesson observed on the previous day, Jamie commented:

> What I did take from yesterday is that "I don't know" or no answer is not good enough and that I need to get a deeper answer from them, either by answering more questions or wording the question in another way

Through these reflections Jamie was considering pumping as a strategy to encourage students to provide more information and develop their thinking further. This "salient outcome" from my model lesson, reported above, generated Jamie's "professional experimentation" (Clarke and Hollingsworth, 2002) evidenced in the next Q&A session where Jamie addressed a moment of contingency (Rowland et al., 2005) caused by a student who did not understand the path difference between waves from two sources/gaps. This was a moment of contingency, because the explanation given and understood by others had not convinced this student. Jamie began to deal with this issue by asking him to recall what path difference meant. The answer given by the student was good, but he still could not tell how many wavelengths out of phase the waves were, so Jamie changed the number of wavelength ($\lambda$) to metres

(m) and asked if the student could now see it (Chin, 2007, p825). His reply showed the concept was now understood.

When I asked Jamie, in our reflection discussion after the lesson, why he chose this strategy he replied:

> In the past I have found that when using a new unit for measurement, it may take time for them to get used to it. Therefore I think of a comparison to try and simplify it in terms they may already know about.

When I asked Jamie what benefits the feedback and reflections with his coach (me) brought to his practice as a physics teacher, he stated:

> …it is nice to see what a model lesson looks like to try and achieve this. (I have seen model English and maths lessons, but they can only help so much.) I also did not know about the 2 speaker sound demo which I am going to use in the future and I also think I gained a new technique whilst questioning. Not accepting "I don't know" for an answer. Querying students further so they work out the answer themselves

These observations are consistent with research on effective CPD for teachers that agrees that professional development activities should be subject specific (Cordingley et al., 2015, 2007; Darling-Hammond et al., 2017; DfE, 2016). Jamie's reflections also show that the coaching sessions generated the sort of enactment and reflection sequences described by Clarke and Hollingsworth's (2002) "change environment" and there is some evidence in Jamie's answers that a change occurred in his "personal domain", e.g. "I gained a new technique whilst questioning".
Driven by Jamie's responses to my questions, I concluded this post-observation interview with the question "What support would you value for your professional development after the coaching programme?". Jamie's answer was:

> I think the one on one coaching programme has been a good way of focusing on elements of lessons I sometimes take for granted. I feel like my questioning has improved, that I have learnt a new type of practical and my confidence has also improved. Although it has taken a lot of time, I believe I gained a lot through the observation and then the discussion of the observation afterwards. Every teacher needs to self-analyse, but analysing a lesson with another teacher gives a wider view of what happened and how to improve it

This reflection strengthens the arguments made above, but it also resonates with Berliner's (2004) observation that "the 5, 7, or more years needed for motivated teachers to acquire expertise might be shortened or be made richer if some coaching and deliberate practice were to take place. Failure to provide these opportunities could restrict what and how much can be learned in the beginning years of learning to teach" (p203).

### 4.1.3 Jamie's lesson

The lesson Jamie planned and taught independently, and that I observed, was a practical lesson where students had to complete one of the "required practicals" from their exam board. Although this lesson didn't specifically focus on questioning, there were some opportunities to observe (and later reflect on) how Jamie used questioning. It mainly shows through a process of questioning after the lesson how Jamie is developing his ability to reflect more effectively on his practice.

The students had been given some research homework to complete in preparation for this practical activity about how to find the speed of a wave. Jamie asked questions to different learners to check what they had found out. Bouncing the questions, "tossing" and "pumping" (Chin, 2004) were observed during

this introduction. In the reflection and feedback session after the lesson I wanted to establish to what extent planning and reflective practice had contributed to this Q&A exchange. Below are my questions and Jamie's answers:

> - Did you prepare these question as part of your planning?
> *I have a rough idea of what pitfalls students fall into with regard of practicals, and I usually focus on the details of the measurements and uncertainties especially. In this practical especially when measuring the period on the oscilloscope.*
>
> - Were some of the questions you asked generated as a result of students' responses? If so, what prompted you to ask these questions.
> *There is a level of detail that students are required to know for the required practicals. I always make sure that there is a chance to delve deep in their understandings but I need to adapt to their responses. There was an obvious gap in their knowledge of how to measure the wavelength and period in this practical, but they had understood that the wave equation was important.*
>
> - How do you know the students who could not complete their research at home understood the purpose of the lesson and what they needed to do?
> *See above + I try and ask at least one question per student to get a feel of what the whole class understands, often bouncing the questions to make sure they understand each other.*

Jamie's responses indicate that he mainly relies on his experience to anticipate learners' misconceptions "I have a rough idea of … pitfalls…" rather than engaging in educational research. However, he recognised the need to "adapt to their responses" and to ascertain that all students develop adequate understanding of practical procedures. "Bouncing the questions" could also facilitate discussion of students' alternative conceptions (Muller et al., 2008). We reflected on these techniques in the post-observation interview from our team-taught lesson, so this indicates that the questioning strategies modelled and discussed have been embedded in Jamie's "personal domain" (Clarke and Hollingsworth, 2002).

Jamie hit a moment of contingency when two groups changed the tension T, the frequency of the wave and the wavelength to then calculate the velocity squared, using the equation:

$$v^2 = \frac{T}{\mu}$$

The purpose of the practical was to calculate the constant $\mu$ for the elastic string used. This was a moment of contingency, because procedurally Jamie expected the students to change only one variable (the tension T) and measure the wavelength $\lambda$, as the frequency was controlled, from the wave equation $v = \lambda f$. In this procedure the students were essentially changing both the independent variable (tension) and the dependent variable (wavelength) by means of changing the frequency.
In our feedback and reflection of this contingency episode Jamie commented:

> I did not see this problem happening, but in future will make it clear that there are 2 methods and to choose one of the options and explain why.
> Any mistake is beneficial as they (hopefully) don't make the mistake again and learn from it. In fact, I often like students to make a mistake and then explain why it is a mistake. I think the one group who did it incorrectly realise why that happened and have learnt from it

This observation revealed that Jamie is developing the confidence to take calculated risks and is encouraging his students to learn from their mistakes. It could be argued that Jamie's progress through the coaching intervention encouraged him to develop reflective practice because "what is important is that the experiences of advanced beginners—cases, incidents, success, and failures—are reflected on and turned into something useful to guide their own teaching practices" (Berliner, 2004, p206). This becomes even more significant in light of a comment Jamie made before we started this intervention "My confidence has recently been knocked from comments from management (after last year's grades)".
When I asked Jamie to explain how he dealt with this moment of contingency he answered:

> When I saw their data, I questioned their logic as to why they had done what they did. I was challenging their procedure to try and make them realise why they had gone wrong. If I had gone "Oh, this is completely wrong, do it again!". They may have just done the same mistake. Questioning is very important to make students realise mistakes.

This was another confirmation of Jamie's reflections and professional learning from the previous sessions. In fact, what he described resonates with the "pumping" approach and socratic questioning employed in my model lesson in using "a progression of open questions to help students think about any problem logically" (Launer, 2017, p783).
Jamie's reflective practice is beginning to develop beyond the immediate events of individual lessons into solutions for further development. In fact, he concluded our reflection session by saying:

> I have a set of videos that I am preparing to use in the future which I am planning on putting on a PlayPosit with questions. This way I can get feedback on what they think is needed to be done

PlayPosit is an online tool I had previously shown to Jamie which allows the user to upload videos and turn them into interactive diagnostic questioning tools. In planning to use this strategy, Jamie demonstrated an increased attention for eliciting learners' misconceptions to establish their starting points (Hattie, 2014), as well as for focussing on learner progress through questions "used to diagnose and extend students' ideas and to scaffold students' thinking" (Chin, 2007, p818).

In summary this lessons seems to show Jamie's development as a more reflective practitioner. For example, he is now more attentive to the events of his lessons that could lead to further development in his teaching and in the progress of his students, as discussed above. In addition, it also shows him using questioning in a more effective and educative way, for example, in seeking to get his students to arrive to better answers on their own – "I was challenging their procedure to try and make them realise why they had gone wrong".

## 4.2 Jess's intervention

Although Jess's focus for her intervention was originally how to introduce equations to A-level students we agreed to shift this focus on identifying and tackling learners' misconceptions for my model lesson, because the only time available for this lesson was when Jess's class needed a revision lesson on forces before their test. In addition, Jess's independent lesson observed by me was an introduction to space and didn't contain any new equations for the students (this again due to the only times available to us for observation). This highlighted some of "the challenges associated with the successful management of these [coaching] mechanisms" (Rhodes and Beneicke, 2002, p299) and came as a reminder that "it is naïve to assume that [*coaching*] is easy to achieve in a school context" (Lofthouse et al., 2010, p10) often because teachers are "already working at or near full capacity" (Foltos, 2013, Kindle Location 448). The

adapted KQ (Clarke and Hollingsworth, 2002) for my model lesson and the lesson observation frameworks for Jess's teaching can be viewed in Appendix 4.

4.2.1 Model lesson

The lesson I modelled with Jess's students was a revision lesson on Newton's laws of motion and it was the last lesson before the class test for this unit. In order to probe students' understanding of Newton's 3rd law (N3) and to elicit their misconceptions I used Socrative – an online tool that allows the teacher to collect students' answers on a question and then to let them vote on the response they think is the most accurate. The question was to explain whether the weight and support force on an object at rest on a table are an example of N3 or not. In their answers learners were also asked to give a reason for their choice. The pupils' responses revealed that most held misconceptions and that their most common answer was similar to this:

> Yes. For every action force there is an equal and opposite reaction force. The battery is in equilibrium as the forces acting on it are all equal and opposite, it has a resultant force of zero

Only one student could provide one reason to explain why the two forces are not an example of N3:

> No, because they are not the same type of forces acting on the battery

However, although partly correct, this answer suggests that if the forces acting on the same object are of "the same type", they could represent N3 pairs, i.e. a common misconception. Allowing students to review and vote on each other's responses, as well as the class discussion of different answers I led after the vote, raised the students' germane cognitive load (Muller et al., 2008) and seemed to facilitate cognitive change by allowing students to present and discuss their misconceptions before a more accurate explanation could be offered by me.

This activity and further diagnostic questions demonstrated that the learners' knowledge and understanding of forces was considerably lower than expected for an A-level class. This finding forced me to drop many of the tasks I had planned and to continue to explore students' alternative conceptions through situations that modelled Newton's laws. In view of the learners' test the next day, it was tempting to adopt a transmission teaching approach (Murray and Male, 2005). Instead, I decided to probe students' misconceptions by asking them to explain their reasoning when giving an answer. This allowed them to challenge each other's conceptions through dialogue and reflective thinking before they were presented with more accurate conceptions by me, similarly to Muller et al.'s (2008) approach to foster "conceptual change". Making this decision modelled how I responded to this contingency episode that led to the need to reshape the lesson, as reported by Bishop (2007) when he said "I think there are lots of decisions that have to be made during the lesson that you're going to leave bits out/put things in depending on what's happening" (p41).

During our feedback and reflection session for this model lesson Jess initially said she teaches in a very different way from me. When I asked her elaborate her statement, she explained that her students do a lot of work using structured worksheets designed by her and that she doesn't talk to them "all the time" like me. This reaction from Jess revealed two important issues. Firstly, Jess's assessment of my teaching approach and intentions highlighted that implicit modelling alone is not enough to enable teachers to appreciate the thinking behind teaching and learning choices (Lunenberg et al., 2007) and that reflective practice is an essential component of teacher education. In fact, the learning and teaching intentions behind the activities I carried out were very different from Jess's interpretation, because the students worked from a worksheet of modified slides from my presentation and were also interacting with the teacher and each other by answering questions and by engaging in classroom dialogue. On further

reflection Jess told me she was very tired that day and that she had not slept well. In addition, her attention was possibly affected by the thought of her students' test the next day.

The second issue revealed by Jess's reaction to my model lesson was that her teaching approach was more akin to guided instruction (Kirschner et al., 2006), as Jess admitted that she mainly teaches through highly structured worksheets and process worksheets (Kirschner et al., 2006, p80). Possibly as a result, for example, all students held the erroneous 'common sense' conception that an object needs a force to be applied in the direction of its motion in order for it to continue to move in that direction, which is highly indicative of conceptions formed from personal experience. This significant lack of knowledge and understanding of some basic forces concepts in her students could be an indication that the guided approach employed by Jess had been ineffective in challenging these alternative conceptions stored in their "long-term" memory (Kirschner et al., 2006). In fact, Kibble (2006) argues that "common sense ideas, based on everyday experiences, lead to an intuitive understanding that does not always produce correct explanations. Experience shows that all moving objects will eventually slow down and stop. This happens when they run out of their 'force'" (p228). Jess was surprised to discover these conceptual gaps in her students too and this realisation allowed me to explain the events of my model lesson and model my thinking in the decisions I made, as well as to link practice to educational theory (Swennen et al., 2008), for example, by reflecting on Muller et al.'s (2008) study on cognitive load and alternative conceptions of students.

In our reflection session we also considered the outcomes of the lesson, which showed very significant impact in the understanding of forces on Jess's students. In fact, by the end of the class all students could apply free body diagrams correctly on moving objects in different contexts from those used at the start of the lesson. Although Jess recognised the approach as effective, she declared that she would be reluctant to use strategies that require her to deviate from her "comfort zone", because she didn't feel confident enough in her knowledge and understanding to deal with students' alternative conceptions in unfamiliar situations. She indicated that her use of structured worksheets acted as a safety net for her and that she needed to know she had all the answers at hand.
The reluctance to take calculated risks and to show potential weaknesses in front of her students could be partly generated by Jess's school context, as in English grammar schools there is a strong expectation to "get the right answer" and attain high grades in exams. This is an aspect that became even more evident in my observations of Jess's teaching.

In summary, the modelling seems to have allowed Jess to 'see' more clearly the issues and challenges that her current practice produces and arguably make her more reflective. However, her reluctance to take risks and her lack of confidence probably means that a more long-term coaching relationship and ongoing support would be needed to effect a change in practice.

### 4.2.2 Team-lesson

The lesson I team-taught with Jess was an introduction to the impulse of a force and we agreed to have a short introduction by Jess to show the equation needed to calculate the impulse on an object, then to ask learners to apply their knowledge and understanding of the equation and of momentum concepts to a real context problem introduced by me. Finally, the students would reinforce their learning of the impulse of a force through a structured worksheet designed by Jess. In taking this approach, we decided to try a more constructivist approach (Leach and Scott, 2003; Palmer, 2005) by allowing learners to develop their conceptions through experimentation in a real context and use more guided instructions (Kirschner et al., 2006) not as a means of developing new knowledge, but as a tool to reinforce students' learning and to assess the conceptions formed during their experimentation. In asking me to lead the real context problem, Jess explained that she was still not feeling confident enough in developing and running an activity with high potential for contingency situations, but that she was interested in observing how her students would react to it.

The real context activity mentioned above was an interactive demonstration of a basketball thrown by a student to me and filmed using the video analysis app "Vernier Video Physics" to generate a Distance-Time (D-T) and a Velocity-Time (V-T) graph of its horizontal motion. From the graphs two methods to calculate the impulse were explored. The first method was to find the change in velocity, multiply by the mass of the ball and divide by the time difference $\Delta t$. The second method was to use the gradient of the V-T graph where the velocity was decreasing to find the mean deceleration and then multiply by the mass of the ball. The two graphs were used to recall features of D-T and V-T graphs through Q&A, so this introduction became an opportunity to probe previous knowledge and understanding too.
The first method was demonstrated from the board, but with the help of students' answers (the coach was asking different questions to the students to get to the solution).

The second method was left to the students to work out and find an answer. A student offered a different method than what the coach had in mind, so both methods were available to the students.
A definite moment of contingency happened when a student suggested a different procedure than what I had in mind.
In our reflective discussion after the lesson Jess and I agreed that I should have let the students try that method first, instead of also suggesting what I thought would be a possible approach, because all students went for my method instead. However, the best method proved to be the student's suggested procedure. In fact, his method returned an impulse that was the same as the one found from the first method used, whilst my method was close, but roughly 0.2 N off.

In our feedback and reflection session I asked Jess what her thoughts on this activity were and she replied:

> It encouraged them to be engaged, but they were a bit shocked the real situation got difficult so quickly. They are scared of failure. This can often be a limiting factor for them. Kids in Comps might do better at this kind of activity than in a Grammar school. Sometimes kids are too dependent on notes and less on trial and error (be confident in making mistakes). Perhaps they should be exposed to this approach lower down the school before they come to A-level. With GCSE I have a different approach and I allow the students to find the equations themselves before I give them the solution.

I also asked her "How confident would you feel in using approaches similar to this which have high potential for contingency situations?". Jess answered:

> At A-level it makes me nervous… I would have done a video beforehand and if things go wrong I then have a back-up plan. With GCSE I would feel more confident. Even with the questions I gave on the worksheet I have the answers, because I lack confidence if I had to do it there and then.

In our discussion Jess agreed that it was beneficial for the students to see that one of them proposed a better solution than the teacher, but she also expressed her reluctance to find herself in a similar situation, because she feels that her role of teacher could be compromised and that her students might lose confidence in her ability to teach them.

Berliner (2004, p209) identifies elements of expert teachers and he includes:

- better problem-solving strategies

- better adaptation and modification of goals for diverse learners and better skills for improvisation

Jess's reflections reveal that she is moving towards expert teaching with her GCSE classes (14-16), but that she still lacks confidence to "allow the students to find the equations themselves" in A-level, because she needs to "have the answers, because I lack confidence if I had to do it there and then". Therefore, Jess was still, at this stage, showing elements of a novice teacher (Berliner, 2004) and, although she could recognise the advantages to allow learners to develop their own solutions and engage in discussions about their ideas and strategies, she was not ready to let go of the security afforded to her by structured worksheets that provided her with the answers and gave little opportunity to her students to deviate from the planned route.
In summary, at this point of my coaching intervention Jess was exposed to teaching ideas and practices that challenged her guided instruction (Kirschner et al., 2006) approach and that proved to be effective in developing her learners' independence. The coaching programme up to this point seemed to enable Jess to develop her reflective practice, but it had not yet produced a change in her own teaching practice, possibly because her confidence was not raised to a sufficient level to enable her to test more constructivist approaches without making her "feel nervous".

### 4.2.3 Jess's lesson

The lesson Jess taught when I observed her practice was an introduction to space and she started by asking her students to discuss what they could remember about space from their previous years. It became quite evident that the learners could not recall much information about their studies on space, so Jess showed some slides from her presentation and explained the information within them to her students.
In our reflection and feedback session I asked her "Did their responses to this first task inform the following episodes of the lesson?". Her reply was:

> Yes, I showed more information and slides from the PowerPoint than I planned to, because their responses were a bit weaker than I expected

This 'change of course' showed some positive change in Jess's attitude to responding to students' progress, although she was still heavily relying on carefully planned slides in her response to this contingent episode.

In the next activity Jess showed a short and fast paced video of the four stages of the life cycle of a star and she later summarised these through a PowerPoint slide. Whilst watching the video the learners were asked to take notes on the four stages.
In reflecting on this activity Jess thought that the students "didn't register anything from the video", so I asked her how the students could use her slide to show their understanding after watching the video. Jess replied:

> Next time I would give the slide with gaps for them to fill as they watch the video. This would help them to focus more and know what they are looking for. This video worked better with last year's class, because there had been more discussion before the video, i.e. there was more input from the students. This class is quieter and less willing to interact with each other.

Jess's response shows a developing reflective agency in recognising the need to adapt her practice to the needs of her students. However, she seemed resigned to the unresponsive attitude of this class, indicating that her students' "persistence in silence sometimes tested the teacher's resolve" (Black, 2003, p10). In other words, instead of looking for strategies that would challenge the students' unwillingness "to interact with each other", she searched a solution that would allow them to work individually.

The rest of the lesson still involved guided instruction approaches to learning, as the students had to cut statements about the stages of the life of a star from a handout and stick them in their notebooks in the correct order. Jess's main concern seemed to be that the students had checked the order, even though she realised that, due to a printing error, the statements were already in the correct order on the handout:

> The students still checked the order to make sure that the teacher had not actually tricked them, so the main learning points were still being met and the activity worked better than I expected, because the students still read all the comments carefully to ensure the order was right

The nature of this unit on space was perhaps more descriptive and 'content-heavy' than more conceptually demanding units, like forces, but I was surprised that alternative conceptions in this topic were not discussed, because space was the main area of studies in Jess's degree and she had identified this unit as her strongest area of physics.
However, Jess ended our feedback session by commenting that this reflective exchange helped her in:

> Making sure you have contingency plans, if students don't respond as expected. Making sure there is more reflection on students' learning during the lesson. Pick on certain students, because I have a tendency to ask students who usually are willing to answer

So, Jess showed a heightened awareness of the need to develop contingency knowledge (Rowland et al., 2005) and to focus on learners' progress in reflecting upon her own practice, as well as to develop effective questioning strategies.

In summary, this lesson and the post-observation feedback session showed some progress in Jess's reflective practice and demonstrated a critical analysis of her teaching and learning approaches linked to students' outcomes and progress. However, she still approached classroom activities through guided instruction strategies and was reluctant to deviate from carefully planned resources she had prepared and seemed unwilling to let go of the 'safety net' such resources provided, even though she considered this unit as her main strength.

### 4.3 Sharing workshop and progress analysis

In this section I will attempt to articulate the main professional learning points highlighted from this study for Jess and Jamie. Clarke and Hollingsworth's (2002) model for teacher professional growth will be used to visualise some of the reflections and enactments that led to this professional change and seek to assess in what ways and to what extent my coaching intervention contributed to their professional growth. Then, I will briefly describe the planning and input Jess and Jamie contributed to in our SPN regional sharing workshop.

4.3.1 Jess's progress

Figure 3 illustrates Jess's starting point and her progress through the coaching intervention.

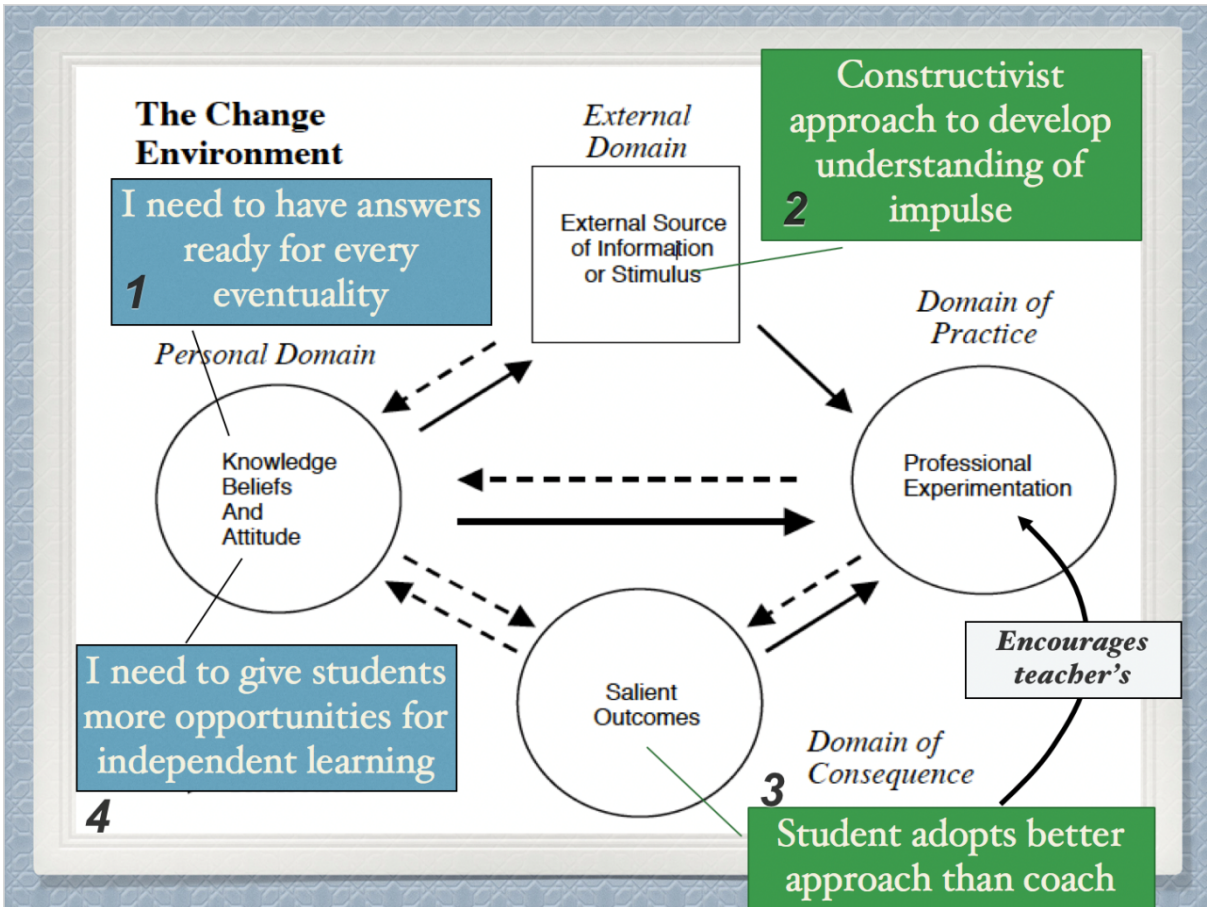



Fig3

One of the greatest limiting factors in Jess's practice (which was identified in the reflection session after my model lesson) seemed to be that she would feel uncomfortable, if she couldn't anticipate her learners' responses, or if she needed to address unplanned questions. So, the core attitude in her "personal domain" was to ensure she taught through structured worksheets and that she had all answers at hand. Therefore, I used a constructivist approach to the impulse of a force in our team-taught lesson in an attempt to generate salient outcomes with Jess. This was achieved when she observed that a student proposed a better approach than me to calculate the impulse from the data collected.
Although this event didn't generate professional experimentation, it encouraged Jess to reflect on the benefits of such approach, which in turn resulted in her reflecting that she needs to give students more opportunities for independent learning, hence beginning to affect her "personal domain" (Clarke and Hollingsworth, 2002).
Although Jess's reflective practice seemed to develop from a position of high dependence on having the correct answers to an intent to give more opportunities for independent learning to her students over the course of this intervention, her "domain of practice" (Clarke and Hollingsworth, 2002) didn't show the agency anticipated by Jess's reflections. This could be a result of her school context and the expectations of senior leaders, parents and students to ensure high standards of attainment are maintained. Educational research suggests that the context of a teacher can be an important factor in their professional learning, as Clarke and Hollingsworth (2002) point out when they say that "change in every domain and the effect of every mediating process are facilitated or retarded by the affordances and constraints of the workplace context of each teacher" (p965).
Therefore, it could be argued that my coaching intervention enabled Jess to develop her reflective practice, but it might not have affected her "personal domain" (Clarke and Hollingsworth, 2002) deeply enough to act on her reflections yet. This outcome raises two questions:

- To what extent do the limitations of the time available for this intervention affect a coachee's progress?

- To what extent is the school context of the coachee a limiting factor in their professional learning?

4.3.2 Jamie's progress

Figure 4 illustrates Jamie's starting point and his progress through the coaching intervention.

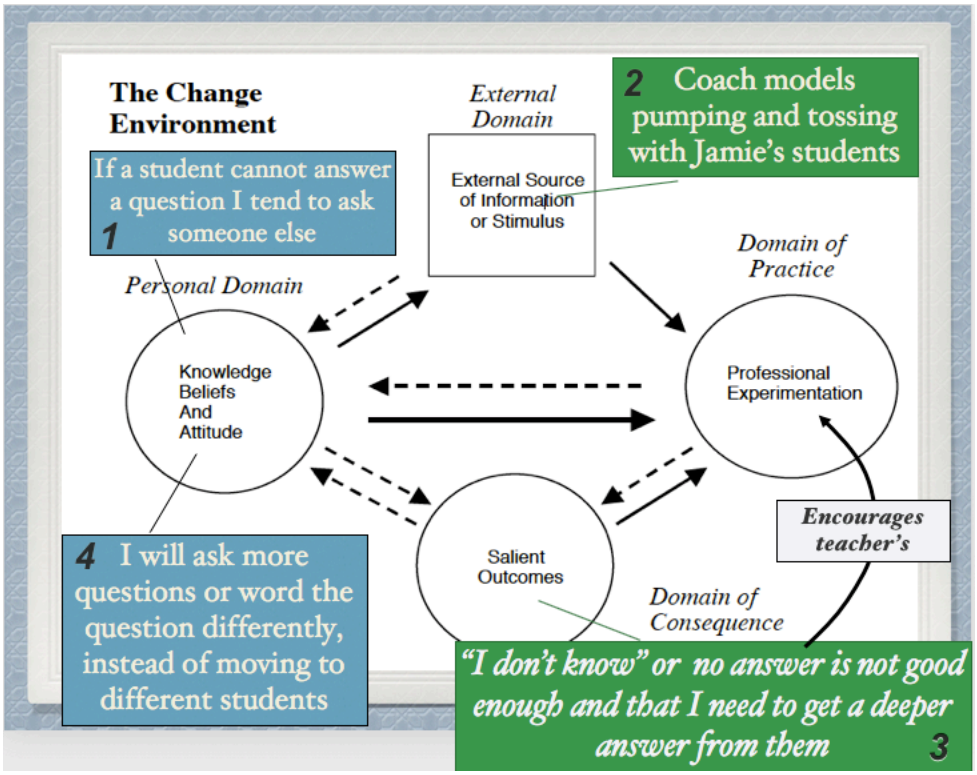



Fig4

Jamie's focus for my coaching intervention was questioning and in his reflections it transpired that he had a tendency to shift a question to students who are more likely to give a good answer, if the student he asked first could not answer. Black (2003) observed this attitude in some teachers who "had to break their established habits" and whose students' "persistence in silence sometimes tested the teacher's resolve" (p10). The external stimuli that I introduced in my model lesson included "pumping" and "tossing" (Chin, 2004) and these induced a salient outcome in Jamie when he observed that a student who seemed uncertain about a particular question eventually contributed a good answer through pumping and tossing. Jamie noted that "I don't know, or no answer is not good enough and I need to get a deeper answer from them". This salient outcome encouraged Jamie's professional experimentation by adopting pumping and tossing himself and this enabled him to further reflect on his learners' progress through these techniques, which are now part of his "personal domain" (Clarke and Hollingsworth, 2002). This was reflected by Jamie when he said "I will ask more questions or word the question differently instead of moving to different students", but it was also observed in his practice.
This example illustrated by Clarke and Hollingsworth's (2002) model shows that the coaching intervention with Jamie had a significant impact on his reflective practice, as well as in his teaching practice, because the reflections fostered by his salient outcomes and professional experimentation produced agency in his teaching practice.

4.3.3 Regional workshop

Further progress was noticed in Jamie during his preparation and delivery of our SPN professional sharing workshop. In fact, he led a session on effective questioning aimed at describing his professional learning journey, hence outlining some of the outcomes described above. But he also did some independent research into other questioning techniques that I had not modelled with him. For example, he researched and used a range of physics "concept cartoons" (Naylor, 2014; Webb et al., 2008) and articulated the benefits of exposing and discussing learners' misconceptions to his audience (Muller et al., 2008; Scaife, 2008). Through this independent research and session Jamie showed professional learning that went beyond the scopes of my coaching intervention, so it could be argued that this project exceeded my expectations in Jamie's case and allowed him to take his professional learning further independently.
Jess also took part in the workshop, but she decided not to prepare a session like Jamie, but simply to describe my intervention and her reflections to the delegates. This part of the workshop was led successfully, but it showed that Jess is still lacking the confidence to expose herself to other colleagues' scrutiny of her work and teaching practice. It could be argued that Jess could benefit from more coaching and support in taking calculated risks with her students and although my coaching intervention fostered reflective practice, it has not yet produced a change in Jess's teaching practice.

The original intent of this sharing workshop was to generate professional learning dialogue and higher CPD hours within the SPN programme. However, only three external participants attended this workshop and a lower than expected number of CPD hours were generated. However, it was evident that this exercise was highly beneficial for Jamie (and partly for Jess), because it drove him to further reflect on his current practice, his progress through my coaching intervention and on wider issues on effective questioning. Therefore, this phase of my coaching model further supported the professional learning of the two participants, as well as the practice of other teachers in the region, who could engage in professional dialogue on effective teaching and learning practice to develop effective questioning and to identify and tackle learners' misconceptions in physics.

## 5. Conclusions and implications

My research question was:

> In what ways and to what extent does an intervention using coaching to facilitate teachers' professional growth in an area of their choice promote teachers' learning?

In conclusion and in answer to my research question, the coaching model I developed and implemented with Jess and Jamie generated some professional learning in both coachees, although Jamie's progress was more evident and resulted in a change in his practice. Whilst Jess's reflective practice showed gradual increments in her ability to critically assess her own teaching in relation to her students' progress, but not sufficient agency to adopt strategies that have higher potential for contingency episodes to arise in her lessons.

A series of limitations were imposed on my model by the nature of the programme and the school contexts of the coachees.
Firstly, due to the limited time I can dedicate to schools involved in the SPN programme I had to limit the number of sessions (or phases) to four. This meant that some aspects of the coaching relationship were carried out via email and other non-contact means. This might have inhibited the coach-coachee relationship, although I had been working with both coachees in a similar capacity for a number of years, so I reasoned that this would not affect the good working relationship that had already been established with them. But with others where I didn't have a prior relationship this might be more problematic.

Secondly, due to time restraints, I could not lead more in-depth sessions to support my coachees in identifying and framing their area of focus and interest for my coaching intervention. Projects like "Linpilcare" (Peeters, 2015) support educators through extensive coaching sessions and would spend several days supporting participants in identifying and developing their own focus for improvement. Since personal motivation is recognised by Berliner (2004) as being "more important for achieving success than talent" (p202), it would seem beneficial to afford sufficient time to coachees to identify a professional learning focus that motivates them deeply to implement a change in their practice.
Thirdly, the coachees' school working environment was a potential limiting factor, because teachers are "already working at or near full capacity" (Foltos, 2013, Kindle Location 448) and in some cases their timetable and other work commitments affected our coaching sessions, for example by not enabling us to have a reflection session straight after a lesson observation, but several days later.
Lastly, the expectations in Jess's school (from a range of stakeholders) were significantly different from those in Jamie's, and the kind of support each would receive from colleagues and senior leaders also differed. For example, Jess's school is a girls grammar school where there are strong expectations to maintain high standards of attainment, so risk taking is generally discouraged by senior leaders and students are also reluctant to show their potential academic weaknesses in front of their peers. This generates greater dependency on detailed notes and on guided instruction (Kirschner et al., 2006) from teachers. Hattie (2014) argues that "school leaders and teachers need to create schools, staffrooms, and classroom environments in which error is welcomed as a learning opportunity, in which discarding incorrect knowledge and understandings is welcomed, and in which teachers can feel safe to learn, re-learn, and explore knowledge and understanding" (Hattie, 2014, Kindle Locations 525-527). So, Jess's professional learning environment might have been a limiting factor, because "change in every domain and the effect of every mediating process are facilitated or retarded by the affordances and constraints of the workplace context of each teacher" (Clarke and Hollingsworth, 2002, p965). This also resonates with Burn et al. (2010) and Hodkinson and Hodkinson (2005) who show the importance of teachers' own attitude to their professional learning in relation to their school cultures.

Having identified some potential limiting factors in my study, there is evidence to suggest both coachees benefited from the coaching intervention received. Jamie focused on improving his questioning techniques and started from a position where he would allow students to withdraw their participation in Q&A sessions by shifting the question they couldn't answer to other, 'more confident', students. During the course of my coaching intervention Jamie observed some questioning strategies modelled by me, including "pumping" and "tossing" (Chin, 2007), and reflected on the outcomes such strategies generated in his students. Jamie engaged in professional experimentation (Clarke and Hollingsworth, 2002) that tested these questioning techniques in his own teaching and became more confident in their use and effectiveness. His learning journey culminated in his independent research and practice with other questioning techniques we had not discussed, nor modelled, as part of the coaching programme, in preparation of his session for our regional sharing workshop (phase 4). In this research of students' misconceptions (Muller et al., 2008) and "concept cartoons" (Naylor, 2014; Webb et al., 2008) Jamie demonstrated agency beyond the scope of the coaching programme and a proactive disposition to professional learning. Jamie has now become a school-based coach for the SPN programme (which is further confirmation of the positive impact of this project on his practice) and he has developed the belief in his "personal domain" (Clarke and Hollingsworth, 2002) that "every teacher needs to self-analyse, but analysing a lesson with another teacher gives a wider view of what happened and how to improve it" (Jamie's comment).

During Jess's sessions a development in her reflective practice was observed, as she critically analysed her practice with increasingly closer relation to her learners' progress. In her reflections she identified the need to provide students with more opportunities for independent learning and more constructivist activities. However, her lack of confidence in dealing with contingent episodes in her lessons (partly due to her school context discussed above) prevented her positive reflections to translate into change in her practice. Evidence of these observations was collected from our reflection and feedback sessions and are

exemplified by comments like “even with the questions I gave on worksheet I have the answers, because I lack confidence if I had to do it there and then”.
It could be argued that Jess could benefit from additional coaching and a school culture that encourages teachers to see errors not as ‘failure’, but as stepping stones for success and further professional learning (Hattie, 2014). It is, therefore, possible that, although progress in reflective practice was observed, my coaching intervention was limited by external factors that could not be controlled by my coaching programme. This should be a reminder for coaches that “it is naïve to assume that [*coaching*] is easy to achieve in a school context” (Lofthouse et al., 2010).

This study has a range of implications for my professional practice and for the wider teacher education landscape.
Firstly, I became more aware of the limiting factors that could affect coaching programmes, like the restrictions of time and the potential challenges posed by the school contexts of coachees.
Secondly, the outcomes of my interventions enabled me to reflect on the importance of teachers’ motivation and personal attitudes to their professional learning (Berliner, 2004). In the future I will strive to offer greater support and dedicate more time to enable coachees to reflect on their professional learning needs more deeply and with greater conviction before embarking in a coaching programme. This is important because such interventions require considerable investments of time and effort from both coach and coachee, so it is imperative that the focus of the professional learning needs of coachees maximises the potential for professional change (Peeters, 2015).

My intentions for this research project were also to explore a coaching model that would retain the bespoke nature of one to one interventions and generate higher numbers of CPD hours within the scope of the Stimulating Physics Network (SPN) programme. In my case the project didn’t generate a significantly high number of CPD hours and it could be argued that it didn’t bear the anticipated benefits to the wider SPN programme. However, I encouraged a large number of teacher educators to participate in professional dialogues related to this project by presenting my model and findings to all Teaching and Learning Coaches (TLC) at a national SPN meeting (around 60 coaches) and I led a seminar on this research and development project at the Groupe International de Recherche sur l’Enseignement de la Physique (GIREP) worldwide conference in July 2018. This seminar was attended by around 50 teacher educators.
The comments collected at the SPN national meeting suggest that TLCs identified the main benefits of my coaching model to include “deep learning”, “more impact in individual practice”, “it would provide a framework”, “more bespoke” and “it encourages more self-reflection and personal development, less reliance on outside support, and helps build confidence of teachers as professionals”. Whilst they identified the main challenges to include “time limitations” and “pressure to meet KPIs”.
The engagement of other teacher educators in professional dialogue about my findings facilitated the reflection on wider implications for the SPN programme and other coaching programmes.
Both these reflections and the findings of my study raise the following questions for teacher education practice and research:

- To what extent do the limitations of the time available for coaching interventions affect a coachee’s progress?

- To what extent is the school context of the coachee a limiting factor in their professional learning?

- What elements should KPIs of CPD programmes focus on to ensure the best professional learning?

Although the findings of this study partly address these questions, further research in these areas could provide additional insights in these important issues.

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**Appendix 1**

# Lesson observation framework

| Class | Gender | Focus of lesson | Time | Date |
|---|---|---|---|---|
| | | | | |

| Lesson narrative | Observations, thoughts and comments (including pre-observation interview) | Review and post-observation questions |
|---|---|---|
| | | |

**Appendix 2**

## PARTICIPANT CONSENT FORM

CUREC Approval Reference:

The effectiveness and scalability of coaching within the Stimulating Physics Network programme

Purpose of Study: To assess the effectiveness of a coaching model within the Stimulating Physics Network (DfE funded project managed by The Institute of Physics). The findings will enable us to suggest innovative ways to develop a sustainable and more efficient model for the professional development of teachers of physics in England and Wales.

| | | *Please initial each box* |
|---|---|---|
| 1 | I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. | ☐ |
| 2 | I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without any adverse consequences or academic penalty. | ☐ |
| 3 | I understand that research data collected during the study may be looked at by designated individuals from the University of Oxford where it is relevant to my taking part in this study. I give permission for these individuals to access my data. | ☐ |
| 4 | I understand that this project has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee. | ☐ |
| 5 | I understand who will have access to personal data provided, how the data will be stored and what will happen to the data at the end of the project. | ☐ |
| 6 | I understand how this research will be written up and published. | ☐ |
| 7 | I understand how to raise a concern or make a complaint. | ☐ |
| 8 | I consent to being audio and video recorded | ☐ |
| 9 | I understand how audio and video recordings will be used in research outputs | ☐ |
| 10 | I agree to take part in the above study. | ☐ |
| 11 | I agree for my personal data to be kept in a secure database for the purpose of contacting me about future aspects of this study. | ☐ |

| | | |
|---|---|---|
| Name of Participant | Date | Signature |
| Name of person taking consent | Date | Signature |

## Information sheet for Teacher Participants

**Title:** The effectiveness and scalability of coaching within the Stimulating Physics Network programme

**Purpose of Study:**
To assess the effectiveness of a coaching model within the Stimulating Physics Network (DfE funded project managed by The Institute of Physics). The findings will enable us to suggest innovative ways to develop a sustainable and more efficient model for the professional development of teachers of physics in England and Wales.

**Background of Study:**
The Institute of Physics has been supporting science departments in a large number of state schools through the Stimulating Physics Network. The Teaching and Learning Coaches in various regions of England offer a bespoke programme of coaching for teachers of physics aimed at developing their confidence, skills and learning and teaching practice, especially for non-specialist teachers of physics.
This study aims at developing an effective model of coaching that can cater for the individual needs of a single teacher, or a small group of teachers, but that has the potential to scale up the reach and influence of the interventions through regional network events where the experiences and skills developed can be shared and reflected upon by a larger number of teachers.

**Methods of Study:**
The study will be divided into the following activities:

1. Discussion with the participating teacher (Coachee) to identify their professional development needs. This will include a structured interview to record the needs identification process which will last approximately 30 minutes and that will be audio recorded.

2. Model lesson led by the Coach (the research student). This will be video recorded and an analysis of the lesson will be carried out with the Coach and Coachee using a revised version the Knowledge Quartet (KQ) model (Rowland et al., 2005)

3. Team planning and teaching of a lesson with the Coachee. The lesson will be video recorded and the video recording will be focused entirely on the teacher and not on the pupils. An analysis of the lesson will be carried out with the Coach and Coachee using a revised version the Knowledge Quartet (KQ) model (Rowland et al., 2005)

4. Coachee's independent planning and lesson observed by the Coach. This lesson will be video recorded and an analysis of the lesson will be carried out with the Coach and Coachee using a revised version the Knowledge Quartet (KQ) model (Rowland et al., 2005)

5. The Coachee will share their learning and reflections with a group of teachers at a regional workshop organised at the Coachee's school. This will be organised as a Link School event, which is one of the activities within the Stimulating Physics Network. At this event structured interviews of three participants will be carried out and feedback forms will be collected from all participants.

As participating teacher I am asking your consent to be involved in activities 1-5 above and your explicit permission to be audio and video recorded.

**What happens to the data provided?** The **research data** will be stored confidentially on the Principal Investigator's password protected computer within a separate confidential folder and within a locked cabinet for paper documents.

Your responses will be anonymised.

**Personal / sensitive data** will be stored confidentially using a secure password protected computer within a separate confidential folder and within a locked cabinet for paper documents.

We will ask all participants for their permission to use direct quotes.

All research data and records will be stored for a minimum retention period of three years after publication or public release of the work of the research, in accordance with the University of Oxford's Policy on the Management of Research Data & Records.

**Will the research be published?**

The University of Oxford is committed to the dissemination of its research for the benefit of society and the economy and, in support of this commitment, has established an online archive of research materials. This archive includes digital copies of student theses successfully submitted as part of a University of Oxford postgraduate degree programme. Holding the archive online gives easy access for researchers to the full text of freely available theses, thereby increasing the likely impact and use of that research.

If you agree to participate in this study, the research will be written up as a thesis. On successful submission of the thesis, it will be deposited both in print and online in the University archives, to facilitate its use in future research. The thesis will be published open access.

**Who has reviewed this study?**

This study has been reviewed by, and received ethics clearance through, the University of Oxford Central University Research Ethics Committee (reference number: xxx).

**Who do I contact if I have a concern about the study or I wish to complain?**
If you have a concern about any aspect of this study, please speak to the relevant researcher (Alessio Bernardelli, +44(0)7447049888] or their supervisor Dr Ann Childs [+44(0)1865274006], who will do their best to answer your query. The researcher should acknowledge your concern within 10 working days and give you an indication of how they intend to deal with it. If you remain unhappy or wish to make a formal complaint, please contact the relevant chair of the Research Ethics Committee at the University of Oxford who will seek to resolve the matter in a reasonably expeditious manner: Chair, **Social Sciences & Humanities Inter-Divisional Research Ethics Committee**; Email: ethics@socsci.ox.ac.uk; Address: Research Services, University of Oxford, Wellington Square, Oxford OX1 2JD

If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact Alessio Bernardelli.

If you are prepared to participate in this research please complete and sign the Participant Consent Form attached and return by email, post to my address in Cardiff or in person at the resulting interview.

Thank you.
Alessio Bernardelli

**Semi-structured interview schedule**

During my research study I intend to interview the participating teacher on the following areas:

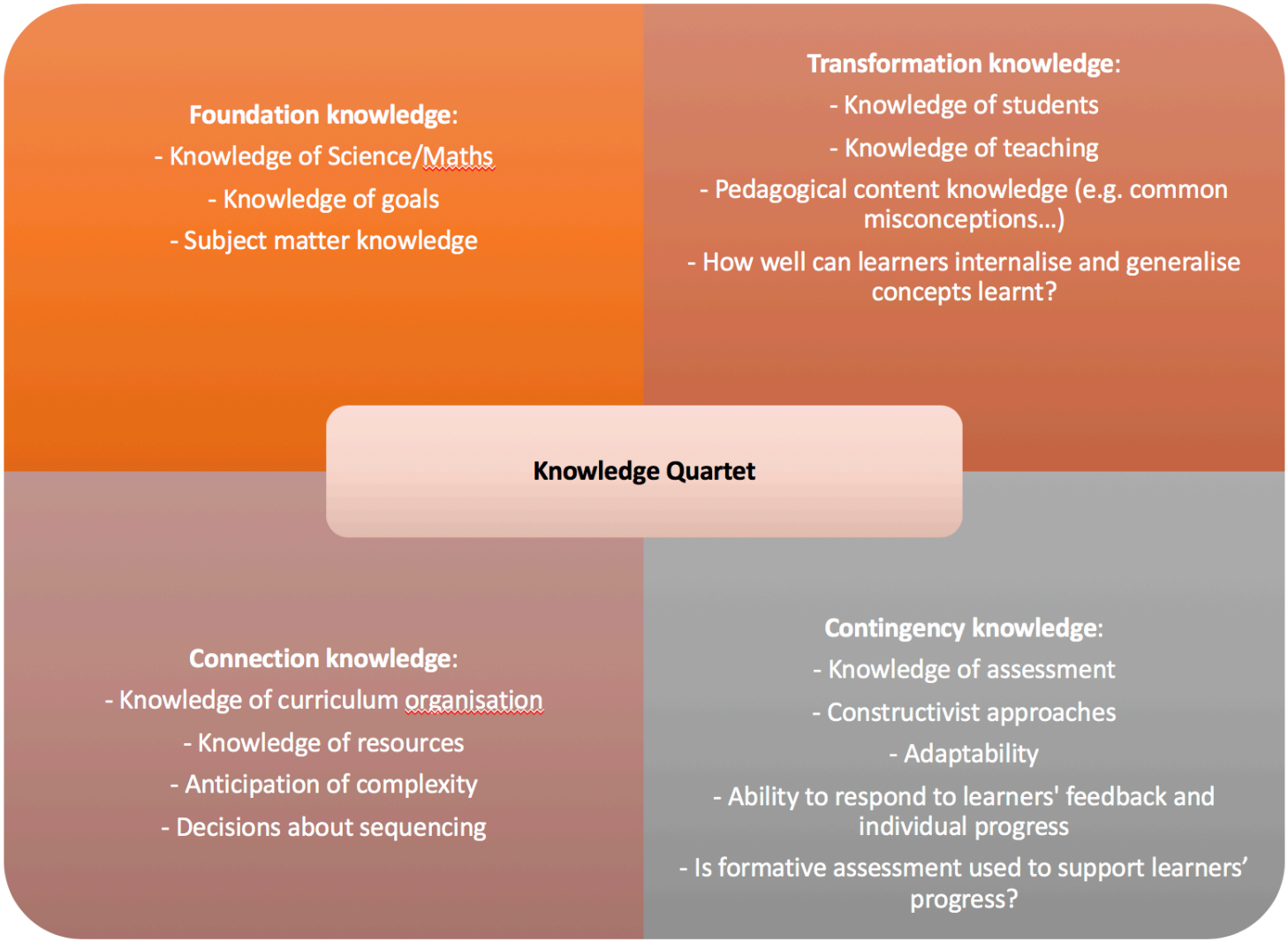
- The teacher's perceived needs and areas of focus for the coaching sessions
- The teacher's perceived competence and confidence in the areas identified before and after the project
- The teacher's opinion on his students' misconceptions in physics before the research project and his reflection on these after the coaching sessions
- I will ask the teacher to reflect and give feedback on the Coach's model lesson and his own lessons

The reactions of the students might also be collected through an anonymised survey focusing on their own knowledge and understanding of the topics developed in the activities of this research project, as well as in their perception of the effectiveness of the strategies, tools and techniques used to develop their knowledge and understanding.

Teachers' feedback will also be collected from the participants at the regional workshop through the SPN evaluation form. Three participants will be interviewed to expand their responses to the evaluation form.

**Appendix 3**

Adapted Knowledge Quartet




Adapted from Rowland et al. (2005)

Model lesson KQ with Jamie

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| **Foundation Knowledge:**<br>- Knowledge of Science: Waves and interference<br>- Knowledge of goals: Introducing the concept of phase and path difference and link to interference pattern<br>- Subject matter knowledge: properties of waves, diffraction, path and phase difference, double slit/two-source interference | **Transformation Knowledge:**<br>- Knowledge of students: first time meeting this class; learners' starting points established through socrative quiz on previous learning. This revealed two main areas (discussed in CK)<br>- Knowledge of teaching: Concepts of superposition, interference, diffraction and phase difference introduced for the first time. For example, two-source interf. demonstrated with 2 speakers and students positioning themselves at different points in the room where they heard louder sounds. A link to superposition and C and D interf. was made in the demo and reinforced using acetate waveforms in their books, which helped them in visualising how the interference pattern is built on a screen. Q&A sessions used effective techniques, e.g. bouncing the question to different students after an answer was offered to check understanding and encourage discussion. Students were chosen by the teacher, rather than picking learners with hands up.<br>- Pedagogical content knowledge (e.g. common misconceptions…): The acetate waveforms made a good link between different ways of representing waves, e.g. wavefronts, waveforms, straight lines… Another aspect that was planned was to make good links between the variables in the equation and how changing each variable affects the distance between max/min. We had some technical difficulties at the start which resulted in slightly delayed start, so a demo of double slit experiment will be moved to next lesson. The qs on light and sound diffraction (slide 5) was an effective question to diagnose the K&U of diffraction within real contexts relevant to students' lives. A good selection of students was asked to contribute to Q&A (not just students with hands up)<br>- How well can learners internalise and generalise concepts learnt? The responses the students gave were encouraging. I didn't ask pupils who put their hands up apart from a few occasions, although a seating plan might have supported this process further. The discussions of learners through the activities and questions asked showed progress in K&U of diffraction and interference of waves, e.g. the position of max and min on the "screen line" for the wave acetate activity was correct for all groups involved, although one group was initially confused on how to do the activity. |
| **Connection Knowledge:** | **Contingency Knowledge:** |

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| - Knowledge of curriculum organisation: Lesson following an introduction to waves and superposition<br>- Knowledge of resources: A range of resources was used, e.g. PPT was used to support understanding of diffraction and path diff linked to phase diff through animations, Socrative established a baseline for the students' previous learning, the IOP TAP resources gave some useful ideas for demonstrations and the Perimeter Institute for the acetate waveforms activity.<br>- Anticipation of complexity: The most challenging concepts (in my professional opinion) are linking path difference with phase difference and being able to visualise how an interference pattern is obtained on a screen. These concepts were aided by the acetate activities (see TK) and path difference animation on PPT (slides 8 to 10)<br>- Decisions about sequencing: A logical progression from Diffraction to superposition of waves and 2-source interference patterns was established. In the next lesson we propose to link the interference from two speakers to the double slit interference from a laser beam | - Knowledge of assessment: Formative assessment was mainly built in the questions asked at different points in the lesson. We run out of time before we could demonstrate double slit, so this will be the start of next lesson<br>- Constructivist approaches: Learners strengthening their own understanding through the acetate waveforms activity. The discussion about the light around corners and sound from a different room supported learners own ideas too. The speakers' demo was useful to enable learners to experience the effects of 2-source interference first hand.<br>- Adaptability: I had to reboot my laptop at the start, so I ran the Socrative quiz from my phone instead to get students on task as soon as possible. Some areas from the quiz had to be revisited at the start, due to the clear lack of understanding on at least two questions from the quiz.<br>- Ability to respond to learners' feedback and individual progress: group support was given during the activity with acetate waves and individual feedback was given through the Q&A sessions in the lesson. Often I asked students further questions in response to their answers to elicit their K&U and help them reach good explanations on their own, instead of offering the correct answer myself.<br>- Is formative assessment used to support learners' progress? Feedback was given orally, but formative assessment might be more evident and relevant in the following lesson. |

# Lesson observation framework (team-lesson with Jamie)

| Class | Gender | Focus of lesson | Time | Date |
|---|---|---|---|---|
| Yr12 | Mixed 1 girl and 7 boys | Young's double slit interference patterns | 1 hr | 19/01/18 |

| Lesson narrative | Observations, thoughts and comments (including pre-observation interview) | Review and post-observation questions |
|---|---|---|
| - Recap questions from previous lesson on the board | - Teacher asked different students from the front. Questions were bounced to diff students after answers were given to compare understanding and achieve greater accuracy. Students called by name, rather than calling ones with hands up. | - Is this a feature of Q&A practice you use regularly? We had a recent inset on questioning (2 weeks prior to this lesson), and this was a technique I came away with as useful and have tried it with a few classes. It seems to make everyone focus on each question and make them listen to each other more. Just with this class, or further down the school? I have used this more in KS4 yr 10 and 11, but I have seen other teachers use this even lower than that. I feel like it works best with the older students, as younger students would just go "I don't know" or "I agree". Even though I got that a few times here, it doesn't happen as often. Is it a result of the model lesson from yesterday? What I did take from yesterday is that "I don't know" or no answer is not good enough and that I need to get a deeper answer from them, either by answering more questions or wording the question in another way. Why do you call students rather than ones who have their hands up? In the past I have experienced that only hands up means you have the same pupils questioning. This way I can make sure everyone answers a questions and differentiate the questions to suit each student. |
| - Diffraction recapped through diagrams on PPT but used to link wavefronts to path difference. Then, path difference between two waves from 2-source/gaps was shown on board (recap from yesterday's lesson). | - Again all students were involved in the discussion and the link between w.fronts and path diff was built together through Q&A. | - A student didn't understand the path difference between waves from two sources/gaps. This was a moment of contingency, because the explanation given and understood by others had not convinced him. You dealt with that issue by asking him to recall what path difference meant. The answer he gave was good, but he still couldn't tell how many $\lambda$ out of phase the waves were, so you changed no of $\lambda$ to m and he could now see it. Why did you choose this strategy? In the |

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| | | past I have found that when using a new unit for measurement, it may take time for them to get used to it. Therefore I think of a comparison to try and simplify it in terms they may already know about. How do you know other students understood? To be honest I did not do a whole class AFL, but from the reaction and faces I think most students understood this. In hindsight a quick quiz here would have been good to make sure they understood.<br>- This part was a recap from yesterday. Why did you decide to go through this section again? Was this useful for the students? I often take the first ten minutes to recap the previous lesson (although this did go a little longer than necessary probably) to make sure that they understand and remember the previous topic before going on with another topic. They may understand a topic one lesson, but the next day or week may forget and need a recap. It also concretes the concept in. The more you go over something the more they understand. I think it was useful for the students as they had shown a deeper understanding of path difference and diffraction in their answers.<br><br>- What other activities could be built in the lesson to engage the students in practicing these concepts? Some better AFL. Either by a quick worksheet, kahoot, mini whiteboards or a socrative. This way I could make sure for definite if they understood. I also did not have a lot of differentiation in the lesson except through questioning. There are students whose targets range from an E to an A so maybe a differentiated worksheet would have done the job. |
| - Wavefronts interference patterns from 2-source discussed on the board. Followed by animation of two sources separation increasing and how that affects the interference pattern.<br><br><u>Coach leading lesson from this point</u>:<br>- Double slit experiment introduced through a demonstration with different slits separations | - Q&A was used to probe understanding.<br><br>- The demonstration did not work as expected and it would have been better to mount the slits on a | - The unfortunate misrepresentation of different laser wavelengths could have caused, or reinforced some misconceptions in students. This was partially addressed by focusing on the equation at the end of the lesson and asking different students to explain what changing each variable would do to x. However, in the next lesson diagnostic |

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| and different wavelengths of laser. The purpose was to link the equation<br>$\lambda = ax/D$ to the effects of changing $\lambda$, a and D had on x. | clamp and stand beforehand. The reasoning behind holding the slits in my hand was to be able to walk back and forth to change D. Also, the separation between max was not evident from the pattern shown from the two lasers and, in fact, it appeared to give the opposite result, i.e. that decreasing the $\lambda$ increased the x distance between max. | questions through Socrative will be given to the students to assess their K&U of these aspects of the topic. The coachee and I discussed this issue and we both agreed that a better and more convincing demonstration of the effect of changing $\lambda$ would be to use diffraction gratings instead. This could be a feature of next lesson too.<br>- What opportunities do you normally have to reflect upon your lessons (outside this coaching programme)?<br>I always have some sort of AFL for the plenary of the lesson. My favourite is a kahoot quiz at the moment, but I have used socrative, a quick quiz which is peer marked, or mini-whiteboards in the past to gain knowledge of the individual levels of understanding of pupils.<br>- What benefits did the feedback and reflections with your coach bring to your practice as a physics teacher?<br>My confidence has recently been knocked from comments from management (after last years grades) so it is nice to see what a model lesson looks like to try and achieve this. (I have seen model English and maths lessons, but they can only help so much.) I also did not know about the 2 speaker sound demo which I am going to use in the future and I also think I gained a new technique whilst questioning. Not accepting "I don't know" for an answer. Querying students further so they work out the answer themselves.<br>- What support would you value for your professional development after the coaching programme?<br>I think the one on one coaching programme has been a good way of focusing on elements of lessons I sometimes take for granted. I feel like my questioning has improved, that I have learnt a new type of practical and my confidence has also improved. Although it has taken a lot of time, I believe I gained a lot through the observation and then the discussion of the observation afterwards. Every teacher needs to self analyse, but analysing a lesson with another teacher gives a wider view of what happened and how to improve it. |

# Lesson observation framework (Jamie's lesson)

| Class | Gender | Focus of lesson | Time | Date |
|---|---|---|---|---|
| Yr12 | 13 boys | A-level practical on standing waves | 2 hr | 25/01/18 |

| Lesson narrative | Observations, thoughts and comments (including pre-observation interview) | Review and post-observation questions |
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| - Some work had been left to the students to research at home about how to find the speed of a wave.<br><br>This part of the lesson was not video recorded, because we deemed it too difficult to avoid filming students' faces in their movements across the classroom due to the practical they carried out. | - Teacher asked questions to different students to check what they had found out. Some students said they found something, but were a bit confused. The questions were bounced to a range of students, who offered some good answers.<br><br>- Three groups started working at the measurements and two groups wrote their plans as | - Did you prepare these question as part of your planning?<br>I have a rough idea of what pitfalls students fall into with regard of practicals, and I usually focus on the details of the measurements and uncertainties especially. In this practical especially when measuring the period on the oscilloscope.<br>- Were some of the questions you asked generated as a result of students' responses? If so, what prompted you to ask these questions.<br>There is a level of detail that students are required to know for the required practicals. I always make sure that there is a chance to delve deep in their understandings but I need to adapt to their responses. There was an obvious gap in their knowledge of how to measure the wavelength and period in this practical, but they had understood that the wave equation was important.<br>- How do you know the students who could not complete their research at home understood the purpose of the lesson and what they needed to do?<br>See above + I try and ask at least one question per student to get a feel of what the whole class understands, often bouncing the questions to make sure they understand each other.<br><br>- Did each group know when they needed to swap and how much time they had for collecting data? |

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| - Due to limited equipment some groups worked on collecting their data first whilst the other groups wrote their plans and methodology for this investigation, i.e. finding the speed of a wave along a rubber string. | they waited. The students were encouraged to read the AQA practical guidance sheet for students on this experiment.<br><br>- The first three groups familiarised themselves with the equipment before collecting data. The use of oscilloscopes proved difficult for most students and it took some time for each group to understand how to use them and set them to a suitable scale to read the frequency of the waves.<br><br>- The teacher supported individual groups by asking questions about the procedure they used, e.g. how long their string was. However, practical skills were not discussed in the introduction to this double lesson, although the theory of how to find the speed of the standing waves along the string was discussed through the Q&A at the start of the lesson. | I do not always keep a hard and fast timescale for the practical's, as I would rather that they take longer and understand it and take a lunchtime than to rush through it and never understand it. I usually give a rough time, but the second group is usually faster as they see how the first group do it.<br><br>- What previous training did the students have on the oscilloscope? Was practicing the use of oscilloscopes one of the aims of this lesson? Why did you choose to introduce oscilloscopes at this stage in the sequence of learning for this group?<br>When introducing the waves topic I first do a lesson on how an oscilloscope works. I then give them a homework on a virtual oscilloscope. I also give many questions about oscilloscopes throughout the course as they come up so frequently. However, the school has many different oscilloscopes and seeing a different one each time is a little confusing for the students. However, I always do a reminder of how to use an oscilloscope before the core practical's to make sure they understand, and in this case, some did not understand so it was important that they do.<br><br>- What level of expertise did you expect the students to have in practical physics before the lesson?<br>They had completed 4 other core practical's by this point, but had many other practical's within the lesson.<br>- Did this expectation arise from previous practical work you did with this class?<br>Previously I had introduced uncertainties, so I expected them to keep using them. I try to add a level of difficulty to each practical they do. In this practical it was the use of an oscilloscope and signal generator.<br><br>- Did the methods used by these students match your expectations? Describe why and how the practical skills of the students did/didn't match your expectations. |

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| | - Two groups changed both the tension T and the frequency of the wave, as well as the wavelength to then calculate the velocity squared, using the equation:<br>$$v^2 = \frac{T}{\mu}$$ | The students completed the practical with little input after the introduction and they will, as always, write up a report on the practical. As I have big groups (because of a lack of equipment) it is not always clear if a student understands the practical until the write up. I was a bit disappointed that one group did not read the practical worksheet clearly and had changed more variables than necessary, but they corrected the work they where doing.<br><br>- From your discussions with the students and observations of their practical skills in this lesson, what aspects of practical physics investigations do you think this group of students needs to develop further and what aspects are they showing good progress in? Explain your answer.<br>They need to expand on their independence and investigation procedure. They are usually willing to start the practical before completely understanding what they are measuring and why, even though they have the full instructions in front of them. They need to fully read and think of what variables are important and why.<br>- How would you address the elements of practical physics the students need to develop further?<br>Practice some non required practicals with little instructions for them to identify and explain their procedure with regards of the variables changed and measured.<br><br>- How did you address this contingency issue? Had you anticipated this potential problem? How could you support your students in future practical sessions in their planning?<br>With regards of the one group, they did afterwards re-do their mistake as they had changes more than one variable. I did not see this problem happening, but in future will make it clear that there are 2 methods and to choose one of the options and explain why.<br>- Were there any benefits (in your opinion) for the students in making this procedural mistake? |

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| - In the last 10 minutes the teacher asked some questions from the board to recap the elements observed from the investigation and discuss the methods used by the students. Support on using the equation for a straight line from the data collected by the students was given through Q&A. | The purpose of the practical was to calculate the constant $\mu$ for the elastic string used. This was a moment of contingency, because procedurally we expected the students to change only one variable (the tension T) and measure the wavelength $\lambda$, as the frequency was controlled, from the wave equation $v = \lambda f$. In this procedure the students were essentially changing both the independent variable (tension) and the dependent variable (wavelength) by means of changing the frequency.<br><br>- Most students seemed confused on how to substitute the equation above into the $y = mx + c$ equation for a straight line. Various attempts were made to explain how to substitute, but many students were still confused.<br><br>- The discussion of the practical also included coming back to the aims of the practical, i.e. finding $\mu$ for the elastic string. This helped the students to get back to their procedure and evaluate what worked well and what needed improvements. | Any mistake is beneficial as they (hopefully) don't make the mistake again and learn from it. In fact, I often like students to make a mistake and then explain why it is a mistake. I think the one group who did it incorrectly realise why that happened and have learnt from it.<br>- Discuss the pros and cons of allowing students to make mistakes in their practicals.<br>Mistakes are an opportunity for learning, but can often led to misconceptions or wasting a lot of time (as time is a precious commodity in learning). On one hand I usually make mistakes so they understand why it happens. There is a risk that it is missed and the mistake is in the practical. This is difficult to rectify as they will have to do it again!!!<br>- How did you deal with this moment of contingency?<br>When I saw their data, I questioned their logic as to why they had done what they did. I was challenging their procedure to try and make them realise why they had gone wrong. If I had gone "Oh, this is completely wrong, do it again!" . They may have just done the same mistake. Questioning is very important to make students realise mistakes. **This is an excellent realisation and it should be linked to the Socratic questions learnt in previous training**<br>- What further support will you give to these students in this area?<br>I have a set of videos that I am preparing to use in the future which I am planning on putting on a PlayPosit with questions. This way I can get feedback on what they think is needed to be done.<br>In the meantime I am planning on doing a small investigation where I have no instructions and they must identify the variables involved and what variable is important to change and which to measure. |

**Appendix 4**

# Model lesson KQ with Jess

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| **Foundation Knowledge:**<br>- Knowledge of Science: Newton's laws<br>- Knowledge of goals: gaining confidence in the use of interaction pairs, free body diagrams and forces on moving objects<br>- Subject matter knowledge: N3 as universal law (all forces come in pairs), N2 applied to study state of motion of bodies, N1 as special case of N2 for resultant force = 0 N | **Transformation Knowledge:**<br>- Knowledge of students: first time meeting this class; learners' starting points established through series of diagnostic questions. Students lacked confidence in N3, free body diagrams and N2<br>- Knowledge of teaching: After establishing students' difficulties in N3, free body diagrams and N2, I tried to address these areas through the activities in their worksheets, through Q&A and through sharing answers and voting for the best response through Socrative.com<br>- Pedagogical content knowledge (e.g. common misconceptions…): All questions and activities in the lesson were designed to tackle students' misconceptions. The object on the table to address misc on N3, the object on the ramp to understand how students dealt with components of a force and tennis ball over the net to address N2. I have used these examples before and found that students often hold alternative conceptions in these situations, so the choice of questions, activities and discussions were deliberate<br>- How well can learners internalise and generalise concepts learnt? I tried to address learners' misconceptions by allowing students to share their ideas first and compare them with their peers, before offering an explanation (see note). In the last activity of the dart being fired by a toy crossbow most students seemed to be able to transfer the knowledge and understanding gained through our previous examples to this new situation, so I believe clear progress could be observed in their responses. |
| **Connection Knowledge:**<br>- Knowledge of curriculum organisation: This was a revision lesson on Forces, so the OCR specs were followed in the content chosen<br>- Knowledge of resources: A range of resources was used, e.g. PPT was used to support understanding of N3, free body diagrams and N2, Socrative established a baseline for the students' previous learning on N3, and later the worksheet and PPT were used as tools to engage the students in their own understanding and to take notes.<br>- Anticipation of complexity: As explained in "Transformation" the examples used were chosen because of their ability to elicit learners' misconceptions, so | **Contingency Knowledge:**<br>- Knowledge of assessment: Formative assessment was mainly built in the questions asked at different points in the lesson. There was an opportunity for peer and self-assessment in the voting of each other's answers on N3 question on Socrative<br>- Constructivist approaches: comparing each other's answers and sharing their alternative conceptions (e.g. in students' explanations of forces on the tennis ball over the net) enables learners' to challenge their own understanding of forces and supported the construction of new thinking and conceptions.<br>- Adaptability: More time had to be spent on N3 and N2 than anticipated, because the students' responses indicated that a number of students still |

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| they functioned as useful springboards to generate discussion and diagnostic questions<br>- Decisions about sequencing: I tried to develop a progression from N3, to N2 and N1, i.e. from universal interactions between two objects to forces applied to one object to study its state of motion. The last activity was designed to contain and assess all the elements we discussed in the previous examples, so the cycle was completed and students could see how this topic was all connected | needed support on these topics. I also felt that teacher led explanations were needed after students' responses were given (on a few occasions), e.g. on components of a force<br>- Ability to respond to learners' feedback and individual progress: See above.<br>- Is formative assessment used to support learners' progress? Voting on each other's answers supported this, but some teacher input was also needed to develop stronger understanding of N3. A Socrative quiz was planned for the end of the lesson, but time didn't allow to do this. |

# Lesson observation framework (team-lesson with Jess)

| Class | Gender | Focus of lesson | Time | Date |
|---|---|---|---|---|
| Yr12 | Mixed 9 girls and 4 boys | Impulse of a force | 1 hr | 07/03/18 |

| Lesson narrative | Observations, thoughts and comments (including pre-observation interview) | Review and post-observation questions |
|---|---|---|
| - Recap of momentum with engaging video of dog on a skateboard.<br><br>- Equation of impulse derived on the board and students taking notes on their notebooks<br><br><u>Coach teaching from here</u> | - The students watched the video and were visibly amused by the dog. The situation was then used to introduce the idea of change in momentum.<br><br>- Students seemed to value the opportunity to write their own notes and the following activities showed that they could recall and effectively apply the equations. | - Why did you choose this particular video? Trying to make a link to a situation the students would not think about normally. How do you think this situation helped the students' understanding? Not much for understandind, but getting them engaged in the lesson. This was effective to get their attention.<br><br>- How important do you think is it to introduce equations to students in A-level physics? They need to develop understanding of equations because old GCSE didn't focus enough on equations, but new years will be better (probably). How do you usually link the equations to the theory, or explanation of the phenomena observed? Using basic situations and then build up to real life situations.<br>What did you think of the activity the coach did? It encouraged them to be engaged, but they were a bit shocked the real situation got difficult so quickly. They are scared of failure. This can often be a limiting factor for them. Kids in Comps might do better at this kind of activity than in a Grammar school. Sometimes kids are too dependent on notes and less on trial and error (be confident in making mistakes). Perhaps they should be exposed to this approach lower down the school before they come to A-level. With GCSE I have a different approach and I allow the students to find the equations themselves before I give them the solution.<br><br>- A definitive moment of contingency was when a student (we couldn't film this as the student was coming to the board) suggested a different procedure than the coach. I should have |

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| - Interactive demo of basketball thrown by a student to the coach and filmed using Vernier Video Physics App to generate a D-T and V-T graph of horizontal motion.<br>From the graph two methods to calculate the impulse were explored. The first method was to find the change in momentum, multiply by the mass of the ball and divide by the $\Delta$t. The second method was to use the gradient of the V-T graph where the velocity was decreasing to find the mean deceleration and then multiply by the mass of the ball. | - The two graphs were used to recall features of D-T and V-T graphs through Q&A, so this introduction became an opportunity to probe previous K&U.<br>- The first method was demonstrated from the board, but with the help of students' answers (the coach was asking different questions to the students to get to the solution)<br>- The second method was left to the students to work out and find an answer. A student offered a different method than what the coach had in mind, so both methods were available to the students. However most students followed the method suggested by the coach. | allowed the students to try that method first, instead of also suggesting what I thought would be a possible approach, because the students went for my method instead. The best method proved to be the student's suggested procedure, which was a nice revelation at the end. In fact, his method returned an impulse that was the same as the one found from the first method used, whilst my method was close, but roughly 0.2 N off.<br>- How confident would you feel in using approaches similar to this which have high potential for contingency situations? At A-level it makes me nervous… I would have done a video beforehand and if things go wrong I then have a back up plan. With GCSE I would feel more confident. Even with the questions I gave on worksheet I have the answers, because I lack confidence if I had to do it there and then.snap |

# Lesson observation framework (Jess's lesson)

| Class | Gender | Focus of lesson | Time | Date |
|---|---|---|---|---|
| Yr12 | Mixed 6 girls and 2 boys | Introduction to space | 1 hr | 18/04/18 |

| Lesson narrative | Observations, thoughts and comments (including pre-observation interview) | Review and post-observation questions |
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| - Students recalled previous knowledge from GCSE on space in their whiteboards | - Some ideas were presented by students and main features like the Milky Way galaxy, black holes, etc… were mentioned. The students didn't seem to be able to recall much information from their GCSE. | - Did their responses to this first task inform the following episodes of the lesson? Yes, I showed more information and slides from the PPT than I planned to, because their responses were a bit weaker than I expected.<br>If so, how did your lesson change as a result? Some students were missing because of Cardiff Uni Open day, so some might have contributed more. |
| - A video about the formation of the solar system was shown and students were asked to write the 4 main stages of the theory of the formation of the solar system | - The video was short and fast paced and the four stages were then summarized by the teacher on the board through a PPT slide. | - How well did the students understand the 4 stages from the video? I think they didn't register anything from the video<br>How did you check their understanding?<br>- How did you use the slide summarising the 4 stages?<br>- How could the students use that slide to show their understanding after watching the video? Next time I would give the slide with gaps for them to fill as they watch the video. This would help them to focus more and know what they are looking for. This video worked better with last year's class, because there had been more discussion before the video, i.e. there was more input from the students. This class is quieter and less willing to interact with each other. |
| - Students were shown a simple diagram of the life cycle of a star and were given the task to research and write the stages of the life cycle of a star. They worked on their research for 15 min. | - The diagram was a useful prop to guide the students in their research, as it helped them focus on the main stages of the development of a star and describe those in detail. This provided a structure for the students to focus on and fostered their independent learning. Students used iPads to help them in their research. Students worked in pairs | - How did the students share their findings? They were making notes to share with their partners and used each other's notes to complete the next task.<br>- How did you check the students' research points led to valuable information being collected and processed by the students? Verbal discussion with students, mainly when they were doing the cut and stick activity. They had the right amount of information collected, as long as the order is fine |

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| - Two areas were emphasised by the teacher for the students' research:<br>1) Chandrasekhar limit<br>2) Schwarzschild radius<br><br>- The students were given tables of information about the stages of the life cycle of stars. The order was scrambled and they had to cut each statement and put it in the correct order in their notes. The statements were divided into two main categories – Sun size stars and stars larger than the sun. Each category had four columns: Name, Note, Energy, Forces (See above for the students' interaction)<br><br>- The Hertzsprung-russell diagram was left for the students to research as homework | and each followed a different route, i.e. sun sized and larger than sun. Then, they should have shared notes.<br><br>- Some students were asked to summarise their research points<br><br>- The statements in the tables seemed to be in the correct order and the teacher might have mistakenly given the tables with the solutions. The students were not told about this and kept cutting the statements. (mistake from the printers)<br>A student came near me to collect a hole puncher and punched holes in his table. He had not cut the statements, so he must have realised they were in the correct order. | that's what they need, but I was making sure they had found the two definitions I asked them to research.<br><br>- What were your reasons for choosing these students to report back? Would you include more students in other activities? If so, how could you involve more students in reporting back? This is clarified by the next activity.<br><br>- How did you deal with this moment of contingency? The students still checked the order to make sure that the teacher had not actually tricked them, so the main learning points were still being met and the activity worked better than I expected, because the students still read all the comments carefully to ensure the order was right.<br>- Did any student realise the tables were in the correct order? It slowly trickled through, but some had already cut them out.<br><br>- Was this a planned homework or left as homework because the time ran out? This was not a planned homework, but it is an activity in the booklet they use to work through as part of their independent study.<br><br>- How has this reflection on the lesson helped you in your teaching practice (if at all)? Making sure you have contingency plans, if students don't respond as expected. Making sure there is more reflection on students' learning during the lesson. Pick on certain students, because I have a tendency to ask students who usually are willing to answer. |