Networked professional learning of physics teachers in a remote area in Scotland

Stuart Farmer

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

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Networked professional learning of physics teachers in a remote area of Scotland

1. Introduction

In 2003 the Institute of Physics (IOP) introduced its Physics Teacher Network to support teachers of physics across the UK and Ireland (Institute of Physics, n.d.). This was in response to the reduction in support for physics teachers available from other sources such as local authority (LA) science advisors, colleges of education or university education departments. It is delivered by a number of Physics Teacher Network Co-ordinators (PNC) who have been given considerable autonomy to support teachers within a geographical area, as well as beyond, through collaborating with each other, others with appropriate expertise, and the teachers themselves. I have been a PNC throughout this time primarily supporting teachers in the north-east of Scotland, see Figure 1.

But what are the needs of teachers of physics in this area where many work in relatively remote and rural schools? How can the IOP Teacher Network best help meet these needs?

This study first determines what the professional learning needs and aspirations of these teachers are and investigates what barriers exist which prevent these being realised. It then investigates how an already existing LA subject group in a relatively remote area can be developed into a more effective and sustainable Networked Learning Community (NLC) providing a subject-based discourse community for seventeen physics teachers across eight secondary schools. This includes how this NLC helps share practice, promote collaboration, and promote enquiry-based professional learning through a programme of events over a year. How well this NLC gives its members access to Knowledgeable Others (KO), from both within and beyond the NLC, and what leadership and facilitation are required to help the NLC function effectively in a sustainable manner are explored.

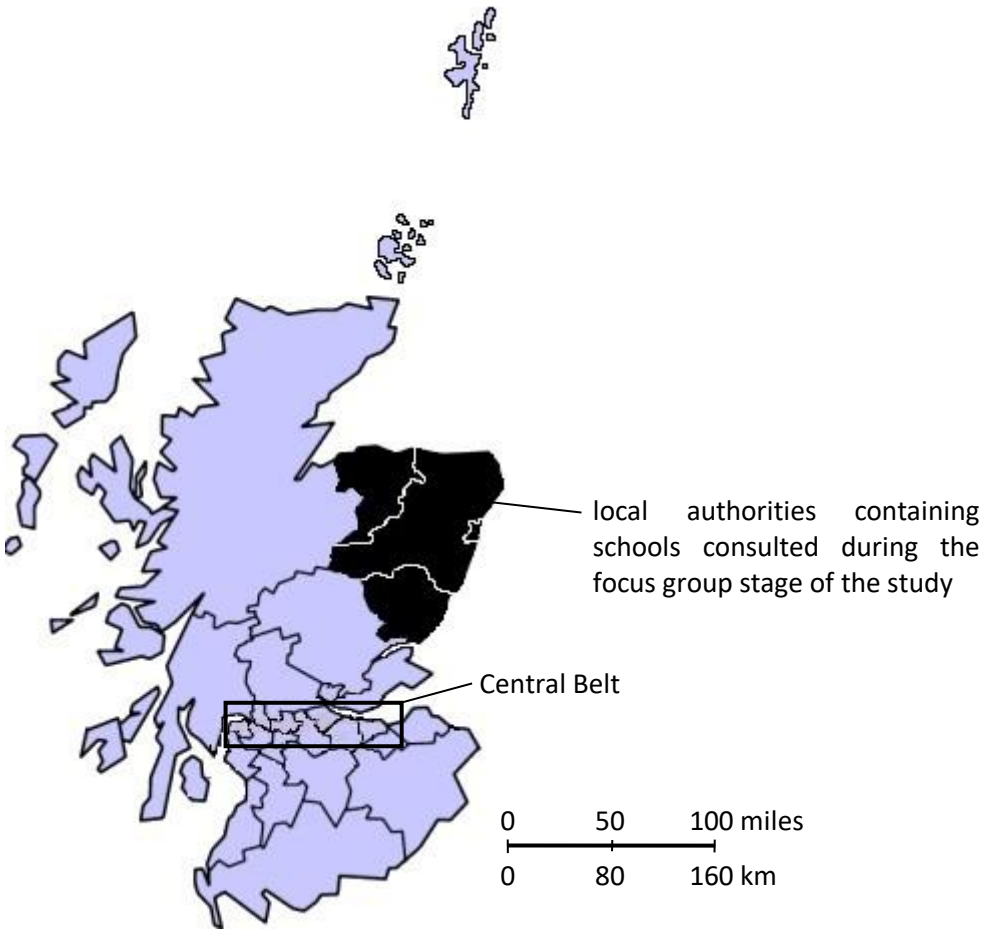


Figure 1: The local authorities areas of Scotland and the location of schools consulted during the first stage of the study relative to the main population centres of Scotland in the Central Belt.

2. Policy Background

In recent years in Scotland, alongside curriculum changes which place greater emphasis on skills and interdisciplinary learning (The Curriculum Review Group, 2004), there have been moves to increase the emphasis on teacher agency, collaborative enquiry and research in the professional learning of teachers. This has been largely in response to a review of teacher education in Scotland (Donaldson, 2010). Enquiry and research are included in the General

Teaching Council for Scotland's (GTCS) standards documents (GTCS, 2012a, 2012b) and the Scottish College for Educational Leadership (SCEL, n.d.-a) was set up to deliver support programmes in Teacher Leadership (SCEL, n.d.-b) which has a strong focus on enquiry approaches. The OECD review of Scottish education also recommended that '*a coherent strategy for building teacher and leadership social capital*' be developed (Hargreaves et al. 2015). It stated:

> "*Teachers who work in cultures of professional collaboration have a stronger impact on student achievement, are more open to change and improvement, and develop a greater sense of self-efficacy than teachers who work in cultures of individualism and isolation. Not all kinds of professional collaboration are equally effective.*" (p140)

As part of the national teachers' contract there is a requirement, and entitlement, for all teachers to undertake 35 hours of professional learning activities per year. Schools also have five in-service days annually.

Apart from a relatively small independent sector, Scottish schools are governed and funded through thirty-two LAs. These vary in size from having two secondary schools, along with their associated primary schools, to a few with more than twenty secondary schools. The geography of Scotland is such that the great majority of its population resides in the Central Belt with more sparsely populated rural areas to the north and south, see Figure 1.

In 2017 it was proposed by the Scottish Government that six Regional Improvement Collaboratives (RIC) be set up (Priestley, 2017; Scottish Government, 2017a) to promote and improve collaborative working across and between LAs. Whilst this potentially provides new opportunities it may be a significant challenge for schools in more remote and rural areas.

Given this policy context, and my role as an IOP PNC, I decided to focus my study on supporting the collaborative professional learning of physics teachers in the north-east of Scotland.

3. Literature Review

This review considers the literature on effective professional learning and professional development and the role of collaboration in this, with a particular focus on the input of KOs and the leadership and facilitation required to provide for the professional learning needs of a network of teachers. As the purpose of the project was to respond to the needs of the network as they emerged, the focus of this review is on the processes of professional learning and collaboration rather than the content delivered. The review begins by looking at defining effective professional learning and development before going on to discussing aspects of collaboration and potential barriers to effective professional learning taking place.

3.1 Defining professional learning and professional development

The terms professional learning (PL), professional development (PD) and professional growth (PG) are often used interchangeably along with a variety of other related terms such as continuous professional development (CPD) and career-long professional learning (CLPL).

Czerniawski et al., (2018, p3) describe PL and PD as '*portmanteau terms*' to describe the formal and informal processes used by teacher educators to improve practice. Tytler et al. (2011, p872), in their interview study of PD of mathematics and science teachers in rural Australian communities, whilst acknowledging differences in the usage of the terms PL and PD use PD as a catch-all term describing '*structures under which teacher professional learning is provided, be*

they externally delivered, school based, or personally arranged'. Weston and Clay (2018, p5) consider it unhelpful to try to separate out the terms: they are used interchangeably. However, Fullan and Hargreaves (2016, p3) reject PD as describing an event attended by teachers. They define PL as including attending events and conferences, collaborative enquiry, reading and other activities that introduce a teacher to something new. They define PD as a change brought about by this PL. If such PD occurs in a teacher it is reasonable to assume that they have grown as a person and professionally, and therefore exhibited PG as described by Clarke and Hollingsworth (2002). Some, mainly in the US, have defined the terms PL and PD in exactly the opposite manner, PD leading to PL (Easton, 2008; Wei et al., 2009, p1). Fullan and Hargreaves (2016, p3) conflate the two terms again when they introduce the term '*professional learning and development*' (PLD) to describe the overlap between PL and PD. Similarly Cordingley (2015, p234) uses the term '*continuing professional development and learning*' (CPDL) to describe activities impacting on teachers and their pupils. It is clear that PL and PD remain contested terms. For many years in Scotland, as in the rest of the UK (Weston & Clay, 2018, p5), the term CPD has been commonly used but a policy change was signalled by the use of CLPL when, in 2012, the General Teaching Council for Scotland introduced new standards for teachers (GTCS, 2012a). Therefore, to be consistent with the use of the terms in Scotland, and as defined by Fullan and Hargreaves, in this paper I will use PL to describe activities and PD more synonymously with the PG described by Clarke and Hollingsworth (2002) in their elaboration of an interconnected model of PG based on empirical research. PD is the change that PL should promote. Although not universal, this was the usage common to many of the teachers interviewed during this study.

3.2 Defining teacher knowledge and expertise

The development of teachers has been linked to the improvement of the education system as a whole in statements such as '*The quality of an education system cannot exceed the quality of*

its teachers' (Barber & Mourshed, 2007, p16), although replacing '*teachers*' with '*teaching*' better allows for the PG of teachers. The purposes of PL are varied, from supporting the growth of domain specific subject knowledge through generic pedagogical knowledge (Lee & Luft, 2008; Shulman, 1986, 1987), to significant systemic changes in teacher agency (Priestley, Biesta, & Robinson, 2015), and teachers' habits of mind (Schneider & Plasman, 2011, p532).

Rowland et al. (2005) introduced the Knowledge Quartet (KQ) as an extension of Shulman's (1986) original conception of Pedagogical Content Knowledge (PCK) where in addition to Foundational and Transformational Knowledge, which correspond broadly to Subject Matter Knowledge (SMK) and PCK, they identify Connection and Contingency Knowledge as important additional knowledge bases for effective teaching. Successful teachers need to have good SMK, to be able to transform this into forms accessible to learners, and to know the context in which they work, if they are to be able to respond quickly and appropriately to contingent moments in their teaching.

Effective PL should promote PG in teachers which impacts positively on their practice and the learning of the people they teach. In order for PL to progress in a known and justifiable manner it is important that theories and a common language to describe matters related to education be developed. However, teacher education has been described as being '*undertheorised*' (Hayward, 1997, p12) and education as an '*immature profession*' (Carnine, 2000, p9), suggesting there is still some way to go on developing a common understanding of the knowledge and skills teachers need to develop against which to determine PG.

In attempting to create a common language to describe educational theories, Korthagen and Kessels (1999) classified these into two forms: *episteme*, general theoretical knowledge and *phronesis*, perceptual theoretical knowledge situated in the context of the moment, '*wisdom of practice*'. The importance and value placed on these will vary for different groups, however,

for both the education of teachers and pupils, theories are important as they allow practices and interventions to be tested and/or measured against them (Korthagen & Kessels, 1999, p15; Clarke & Hollingsworth, 2002, p947).

Having reviewed ideas on PL and PG, and the role of theory in this, the literature on teacher learning and how teachers can grow to develop a high level of adaptive expertise (Berliner, 2004, p203), is now considered. It is widely recognised that the most desirable outcome for PL is the development of teachers with adaptive expertise, exhibiting life-long learning and a high level of teacher agency building on notions such as Schön's (1983) '*reflective practitioner*' or Sachs' (2003) '*activist teacher*'. As long ago as the 1930s Dewey (1933) described reflection as the deliberate thinking about practice. Loughran (2002, p13) states that reflection has developed a variety of meanings, however, one element common to many is the notion of a clearly defined problem to be addressed by the reflection.

Research has shown that expertise can take many years to develop (Berliner, 2004; Furlong & Maynard, 1995). Berliner (2004) presents a model consisting of five stages of development: novice; advanced beginner; competent; proficient, and expert. Such stage models are useful in providing a language for describing the PG of teachers but are inevitably a simplification of the complex reality of teacher development (Burn, et al., 2003). Berliner (2004, p201) estimates that teachers are likely to take around 7 years of experience to reach the proficient level. Whether or not a teacher then goes on to become an expert is not assured and this may well be significantly influenced by ongoing PL, mentoring, and coaching (Rhodes & Beneicke, 2002, p305; Darling-Hammond et al., 2017, p12). This highlights that teachers at different stages in their careers have different PL needs but the aim should be to develop teachers with adaptive expertise (Berliner, 2004, p200). This is consistent with building SMK and PCK (Lee & Luft, 2008; Shulman, 1986, 1987) and the Connection and Contingency knowledge of Rowland et al. (2005). To support teachers through Berliner's stages towards adaptive expertise where they

show fluid performance, and to maintain interest and motivation beyond, effective CLPL is necessary.

3.3 Effective PL

Having considered professional knowledge and expertise, models used to describe PG are now reviewed along with features of PL which facilitate PG. The development of effective PL activities requires an understanding of the processes of teacher PG and a model is proposed by Clarke and Hollingsworth (2002, p951). This is a complex interconnected model which has evolved from simplistic linear models, such as that by Guskey (1986, p7), and was developed using evidence from three extensive, longitudinal studies of Australian mathematics and science teachers (Clarke & Hollingsworth, 2002, p951). In the Clarke and Hollingsworth model, change in four interconnected domains can occur through both enactment and reflection. They describe that historically most PL activities are '*one-shot*' workshops designed to address a perceived teacher deficit and how there is '*convincing evidence of the failure of "one-shot" professional development approaches*' (p948), at least in promoting widespread systemic changes in practice. They go on to describe that for real PG teachers need to be '*active learners shaping their professional growth through reflective participation in professional development programmes and in practice*' (p948): a growth in teacher agency. In extensive reviews of what makes PL effective, extended teacher PL activities, of two terms or longer, are demonstrated to be more effective than short-term ones, although one-off events can address specific aspects of teacher SMK and PCK and have an impact on a narrow aspect of pupil achievement (Timperley et al. 2007:104; Cordingley et al., 2015, p4).

Hargreaves and Fullan (2012) also refer to a deficit model when describing a '*business capital*' approach to PL which they argue leads to a loss of teacher agency and a culture of compliance which ultimately stifles both the PG of individual teachers as well as the development of the

wider education system. They advocate the development of both teacher agency and the education system through the growth of '*professional capital*'. They break professional capital down into three components: '*human capital*', the knowledge and skills of teachers; '*social capital*', the interactions between teachers, and '*decisional capital*', the ability of teachers to make discretionary judgements. It can be seen from this model that the development of professional capital and particularly its component of decisional capital, i.e. adaptive expertise and contingency knowledge to allow effective decision-making, rely on the development of both the human capital of teachers' SMK and PCK, and the social capital of collaborative PL. Bell & Gilbert's (1996) model of teacher development also encompasses three components: social, personal and professional. These models emphasise the importance of social or collaborative working in effective PL. This is consistent with Wenger's (1998, p3) concept of a '*Community of Practice*' (CoP) where although learning is described as an individual process, we are social beings and learn from each other, often making meaning in a social context.

This extended, social nature of PL is included in the general research consensus which has evolved around identifying the features of effective PL which have the greatest impact on teacher PG and pupil outcomes (Darling-Hammond et al., 2017; Desimone, 2009; Garet et al., 2001; Stoll, Harris et al., 2012). These features are summarised by the ten principles identified by Timperley (2008) in her synthesis of the research on effective PL:

1. Focus on valued student outcomes
2. Worthwhile content (in achieving valued student outcomes)
3. Integration of knowledge and skills
4. Assessment for professional inquiry
5. Multiple opportunities to learn and apply information
6. Approaches responsive to learning processes
7. Opportunities to process new learning with others
8. Knowledgeable expertise

9. Active leadership
10. Maintaining momentum (sound theoretical knowledge, evidence-informed enquiry, supportive organisation).

Timperley's ten principles do not operate independently: rather, they are integrated to inform cycles of learning and action, such as those described by Korthagen & Kessels (1999, p13), Timperley et al. (2007, pxliii), and Donohoo & Velasco (2016, p6). Timperley (2008, p6) also identified four other aspects from the evidence base:

1. Student learning is strongly influenced by what and how teachers teach
2. Teaching is a complex activity
3. It is important to set up conditions that are responsive to the ways in which teachers learn
4. PL is strongly shaped by the context in which the teacher practises.

The literature suggest that effective PL for teachers should be sustained, embedded in the context of the teacher, integrate new and worthwhile SMK with PCK, with input from KOs to ensure PD occurs rather than the '*sharing of ignorance*' (Guskey 1999, p12), be truly collaborative rather than display '*contrived collegiality*' (Hargreaves & Dawe, 1990), and be focussed on pupil outcomes. The CUREE (2018) review of subject-specific PL states that "*An important feature of effective CPD is that it is either focussed directly on developing knowledge or practice in a subject area, or focussed on developing an aspect of teaching and learning in ways that are contextualised for specific subjects*" (p5). It also cautions that "*There is also a need to ensure that research- and evidence-informed practice does not become distorted, and distract from a focus on subject-specific approaches and implications*" (p7).

Whilst there is general consensus around the features of effective PL there is rarely sufficient detail in studies, or precision in the definition of terms, to provide specific guidance to those

designing PL activities (Scher & O'Reilly, 2009, p235; Stoll, Harris, & Handscomb, 2012, p2; Wayne et al., 2008, p470), thus creating problems for those considering replication or attempting to draw conclusions. Desimone (2009) highlights the need for a better core conceptual framework for PL to enable better comparisons of its effectiveness. Kennedy (2016, p971) states that whilst many studies into effective PL sort programmes according to their design features, these are poor predictors of effectiveness as there are more complex, subtle variables at play. For example, in relation to the effectiveness of professional learning communities (PLC) Kennedy (2016, p972) states "*it is important to examine the content such groups discuss and the nature of the intellectual work they are engaged in*" rather than only considering the easily identified features of the PLC such as the frequency of meetings. Similarly for networks Bell et al. (2005, p6) "*The size of the networks appeared to bear little relation to their effectiveness, suggesting that it is the quality of the collaboration between local clusters within networks which effectiveness may turn*".

Much of the general research consensus around the features of effective PL have been arrived at through the use of meta-analyses and meta-syntheses of research studies. Whilst there have been very successful proponents of the use of the statistical technique of meta-analyses, and meta-meta-analyses, such as Hattie (2003, 2009), this technique, especially in terms of using effect sizes to compare different approaches, has also been criticised as it does not take adequately into account the quality and detailed differences in the original studies (Cheung & Slavin, 2016; Simpson, 2017; Wiliam, 2016). Meta-syntheses, more narrative studies where experts identify and read relevant studies before summarising the main findings, are subjective in nature (Wiliam, 2016, p73), even after peer-review. However, such meta-syntheses can provide a useful overview and identify important features of the research in that field of study.

When planning effective PL the literature suggests that it is perhaps not so important to consider the desirable features of the PL but to first consider the needs of the teachers involved and to be clear about the goals of the PL before then deciding on the features of the modes of delivery (Deans for Impact, 2016, p6; Fletcher-Wood, 2018, p6). As put succinctly by Wiliam (2007, p188) "*content, then process*". Aligning PL to shared goals and needs is a feature of high-performing education systems (Jensen et al., 2016). It is therefore essential that the purposes of the PL always be kept uppermost in mind, nevertheless the fact that PL is a collaborative social activity means this is an important feature to consider.

3.4 Collaboration

Over the last two decades there has been a significant growth in the literature which shows that collaborative PL impacts on both the professional practice of teachers and the outcomes of their pupils (Cordingley et al. 2003; Cordingley et al. 2005; Cordingley et al. 2015; CUREE 2018; Darling-Hammond et al. 2017; Harris et al. 2017; Lieberman et al. 2017; Stoll et al. 2006; Timperley et al. 2007). Collaborative working can manifest itself in various forms, both informal and formal, for example, Darling-Hammond et al. (2017, p9) define collaboration as "*from one-to-one or small group interactions to school-wide collaboration or exchanges with other professionals beyond the school*". Informal PL can occur between colleagues on a daily basis in staff bases, over lunch, or whenever the opportunity arises and is often serendipitous (Hodkinson & Hodkinson, 2005; Mawhinney, 2010; McNicholl, Childs, & Burn, 2013; Williams, 2003; Williams, Prestage, & Bedward, 2001). School social structures and networks are often defined by the teachers themselves and not significantly influenced by formal school organisational features (Cole & Weinbaum, 2010, p94). More formal PL arrangements can also take many forms including PLC, teacher learning communities (TLC), or networked learning communities (NLC). TLC are often associated with the work of Wiliam on PL related to Assessment for Learning (Wiliam, 2016). PLC are frequently school-based and may encompass

a whole primary school but in larger secondary schools they are more likely to be organised around departmental or cross-curricular teams of a few teachers (Bolam et al., 2005; Stoll et al., 2006). NLC can link teachers in a number of schools and may also include partners from universities, professional bodies or the wider community (Bell et al., 2005; Chen, 2018). Even within these formal arrangements the informal elements can be highly valued and effective (Kennedy, 2011, p33), if difficult to quantify. There are various approaches such teams may take in their PL such as coaching, mentoring and peer networking (Rhodes & Beneicke, 2002), lesson study (Lewis, Perry, & Murata, 2006), lesson rounds (Philpott & Oates, 2017), action research (Fazio & Melville, 2008), and practitioner enquiry (Gilchrist, 2018). All such collaborative practices display characteristics of Wenger's (1998) CoP whereby groups work towards a shared purpose through shared knowledge, shared values, mutual engagement, and joint enterprise. In preference to CoP, Tytler et al. (2011, p878) describe '*discourse communities*' as a more useful term to describe the diverse connections made by teachers. This is also a good description of an IOP-supported NLC of teachers from a group of secondary schools. The context of Tytler et al.'s work with teachers across schools in a remote area of Australia is similar to my own in the north of Scotland. In my professional opinion '*discourse community*' better describes the fairly loose connections between these teachers than CoP which might imply closer connections and possibly a common workplace.

Mentoring and coaching are forms of collaborative PL which tend to be sustained over significant periods of time and the terms are used somewhat interchangeably (Rhodes & Beneicke, 2002, p301). Mentoring is commonly used to support the PL of beginning teachers where an experienced subject mentor supports the mentee in an expert-novice relationship such as during a teacher's probationary period (GTCS, n.d.-a). Coaching involves the coach supporting those being coached develop their own PL. Coaching and mentoring have been seen to provide significant gains (Kraft, Blazar, & Hogan, 2018, p577) but tend to be relatively expensive in staff time and to have relatively few beneficiaries (Wayne et al., 2008, p470)

which raises issues about their scalability as a means of supporting CLPL. However, peer-networking of subject teachers, both within and between schools, provides a means of forming a relevant discourse community and "*working together to enhance information exchange, dissemination of good practices, and the organisation of mutual support and learning*" (Rhodes & Beneicke, 2002, p301).

Secondary schools are commonly split into departments or faculties: more than administrative units, they provide the professional identity and context for many secondary teachers (Brooks, 2016; Helms, 1998; Siskin, 1994). As well as generic pedagogical knowledge, secondary teachers have SMK and PCK (Shulman, 1986, 1987) which is specific to the subject(s) they teach and the department provides the locus for much professional discussion and collaboration. Subject departments therefore act as discourse communities and are the primary site for the PL for many secondary teachers (Tytler et al., 2011, p872).

Effective collaboration within departments is an issue for teachers in small schools in rural and remote geographical areas as there are few subject colleagues within any one school, and adjacent schools are some distance apart (Hargreaves, Parsley, & Cox, 2015, p306; Tytler et al., 2011, p877). School in-service days, which are usually co-ordinated across a LA, provide opportunities for collaboration between schools, but there is evidence from England that these are rarely used well for collaborative PL (Bubb & Earley, 2009, p8). Schools in more remote areas tend to be some distance from universities, science and engineering industries, and other sources of KOs in physics, science or education. In addition, in many countries, the recruitment and retention of staff has been shown to be difficult in rural and coastal areas, particularly in shortage subjects such as science and mathematics (Azano & Stewart, 2016; CUREE, 2018; Kaden, Patterson, Healy, & Adams, 2016; Kitchenham & Chasteauneuf, 2010; Lock et al., 2009; Seith & Hepburn, 2017; Tytler et al., 2011). The provision of effective PL, as well as the support and valuing of the teacher by their management, is a factor which can

increase teachers' satisfaction in their work and assist in the retention of teachers (Allen & Sims, 2017; Lynch et al., 2016; Mostafa & Pál, 2018; Sims, 2017) and improve pupil outcomes (Robinson et al., 2009). However, the provision of effective collaborative PL requires good leadership and facilitation.

3.5 Leadership and facilitation of PL

As for any activity PL requires leadership and facilitation to be effective. "*Professional development does not just happen – it has to be managed and led.*" (Bubb & Earley, 2007, p28). This includes those undertaking the PL demonstrating agency and taking a lead themselves as well as looking for support from outside this group. Without one or more individuals showing some vision and drive it is unlikely that good progress towards effective PL will be made. However, this requires appropriate support to be in place. As claimed by Frost (2011):

> "*...teachers really can lead innovation; teachers really can build professional knowledge; teachers really can develop the capacity for leadership, and teachers really can influence their colleagues and the nature of professional practice in their schools. However, what is abundantly clear is that teachers are only likely to do these things if they are provided with appropriate support.*" (p57)

For PL to be firmly embedded in the context of the participants then it is important to empower the participants to clarify their own agendas and pursue the goals they have identified for themselves (Frost, 2014, p71). Such empowerment should help build adaptive expertise (Berliner, 2004), as well as teacher agency (Priestley et al., 2015), within the participants. This is consistent with Sachs' (2003) description of developing teacher professionalism through learning, participation, collaboration, co-operation, and activism, and

where the collaboration involves both collegial discussion within their immediate departmental or school discourse communities but also working with, and being challenged by, others from beyond these groups.

In their review of the literature on effective PLC, Stoll et al. (2006, p226) identify a number of characteristics of effective PLC which require good leadership and facilitation in order to be successful, such as: shared values and vision; collective responsibility; collaboration; inclusive membership, and mutual trust, respect and support. In addition to these characteristics Bolam et al. (2005, pi) also identify four key enabling operational processes for effective PLC of which leadership and management is highlighted as one, but the others (optimising resources and structures; promoting individual and collective learning, and explicit promotion and sustaining of effective PLC) all require good leadership. Priestley et al. (2015, p89), highlight that whilst many benefits have been claimed for PLCs and networks of teachers in terms of effective PL, that the literature can be over-positive. Successes will be more likely reported than failures. The effectiveness would seem to be dependent on the quality of what the PLCs and networks do, and on the connections made, resonating with Kennedy (2016, p972). However, in their review of the literature, Bell et al. (2006, p10) found that there was little detail of how leaders and facilitators ensured PLCs and networks operate effectively.

Daly (2010, p3) states that "*merely providing time and directives to 'work together' does not necessarily result in meaningful collaboration*". For effective PL in a group it is not only important to have expertise within the group, and time and space to share that expertise, but there must be sufficient leadership and facilitation to be able to identify who has the expertise and to be able to access and co-ordinate it (Coburn, et al., 2010, p48). A crucial stage for this is during the negotiation of the focus or goals of collaborative work (Robutti et al., 2016, p680). Whilst there may be those with sufficient leadership and facilitation skills within a group it is likely that there is a need to draw on expertise from outside.

3.6 Knowledgeable others

In her summary of the research on the PL which has the most impact on pupil outcomes, Timperley (2008) identifies that PL should include opportunities for collegial interaction and the input of external expertise. KOs can bring three main types of expertise:

1. SMK, PCK or research knowledge not otherwise available in the group
2. The ability to challenge the status-quo in order to move the PL forward
3. Facilitation skills (Cordingley et al., 2007, p19).

In his account of developing effective PL through practitioner enquiry Gilchrist (2018, p25) describes not only the importance of supportive school leadership in supporting the PL of teachers but that of a significant KO. In this case it was a university lecturer able to provide research knowledge, challenge, and facilitation to teachers directly, and to school leaders enabling them to better facilitate the PL of others in their schools.

Weston and Clay (2018, p6) highlight the importance of an evidence informed PL process of engaging with good KOs who can support, challenge, model practice and inspire and that expert facilitators are needed to "*make it a disruptive process that helps us overcome the limitations of our own thinking*". They also state that subject associations, such as the IOP, as well as attendance at conferences and contact through social media can connect teachers with suitable KOs (Weston & Clay, 2018, p7).

An important role of KOs can be to support teachers in the gathering and use of research and evidence to inform their practice (Robutti et al., 2016, p677), a key feature of enquiry processes.

3.7 Enquiry-based PL

Enquiry-based cycles of teacher PL have been shown to have impact of pupil outcomes (Timperley et al., 2007, pxliii; and Donohoo & Velasco, 2016, p6). Since the introduction of new standards for teachers (GTCS, 2012a), there is an expectation that Scottish teachers undertake such enquiry throughout their career as a day-to-day part of their work, '*inquiry as stance*' as described by (Cochran-Smith & Lytle, 1999, p288), as illustrated by the follow extracts:

"*Teachers ... are expected to...:*

- *systematically investigate, analyse and evaluate the impact of practice;*
- *critically question and challenge educational assumptions, beliefs and values of self and system;*
- *critically engage with a range of educational literature, research and policy to make meaningful links to inform and change practice, where appropriate;*
- *work to create, contribute to, and lead a collegiate culture, through collaborative enquiry...*". (p8)

and

"*Professional Actions [of teachers]:*

- *develop and apply expertise, knowledge and understanding of research and impact on education;*
- *develop and apply expertise, knowledge, understanding and skills to engage in practitioner enquiry to inform pedagogy, learning and subject knowledge;*
- *lead and participate in collaborative practitioner enquiry*." (p10)

However, this requires the creation of appropriate cultural conditions in Scottish schools as described by Kelly (2016, p27) in relation to teacher leadership and Gilchrist (2018) in relation to practitioner enquiry. There appears to be a number of barriers currently preventing these practices becoming widespread.

3.8 Barriers to participation in PL

Despite the policy drive in Scotland towards creating greater teacher agency and a "*culture of 'pull' from teachers rather than 'push' from outside the classroom*" (Donaldson, 2010, p10), Livingston (2012, p169) reports that not every teacher feels ready or able to do this without support.

The 2013 TALIS study (OECD, 2014, p112) identified a number of barriers for teachers participating in PL. Around half of teachers in the international sample identified that PL conflicted with their work schedule and that there were no incentives for them to participate in PL activities. Other significant barriers were: PL being too expensive; no relevant PL being available; lack of time due to family commitments, and lack of employer support.

Kelly (2016), in a study involving over 1000 Scottish teachers into the issues around developing teacher leadership, identified similar barriers:

> "*The most common responses in the workshops were time, workload and confidence. However, there was also frequent mention of a lack of opportunities for experience, appropriate professional learning, recognition, support, encouragement and trust. There was very often the mention of the role of hierarchies in Scottish education in stifling creativity, innovation and leadership. ... The issue of lack of cover came up frequently, as did unnecessary bureaucracy.*" (p12)

In a study of 23 PLCs in the Netherlands, Prenger et al. (2017, p84) reported high workload and lack of time hindered collaboration due to lack of preparation for, and absence from, meetings. They also reported (p88) that geographical issues did not have a significant impact on PL in networked PLCs, however, the Netherlands is much more densely populated than the north of Scotland. Difficulty accessing effective PL is an issue affecting teachers in rural areas of Australia (Tytler et al., 2011, p872) and even teachers in large schools in densely populated areas can experience isolation (Ali Ostovar-Nameghi & Sheikhahmadi, 2016; Flinders, 1988). Teachers working in small departments in remote areas have a very limited pool of colleagues with which to interact, especially in their own subject domain, an important factor in effective PL (CUREE, 2018).

3.9 Developing and sustaining networks and PLC

There is a growing knowledge base on the features, structure and possible impacts of networks and PLCs (Bell et al., 2005; Bolam et al., 2005; Stoll et al., 2006). For example, in a systematic review of 119 studies of between-school networks of three or more schools, with a particular focus on 19 international studies, Bell et al. (2005) found that school-to-school collaboration does impact pupil outcomes. The more effective networks had narrower and more specific aims and targeted their efforts on particular groups of pupils, often those with specific needs which were addressed by the network drawing on a wider range of resources and expertise than would have been accessible in a single school. Bell et al. acknowledged that these findings could have arisen, at least partially, because it is easier to measure the impact on smaller groups of pupils.

There is less knowledge about how these networks come about or how to build such networks more effectively (Coburn et al., 2010, p34). A number of reasons why individuals reach out to form connections in a social network, have been identified including:

- *homophily*, people reach out to similar people
- *proximity*, people reach out to those close by
- *expertise*, people reach out to those perceived to have useful knowledge.

Whilst much of the research in this area has focussed on the characteristics of the person or of the connection, little research has been undertaken on the social and organisational context which might shape the choice of connections, although there is some evidence in education that organisational structures, such as school departments, influence the configuration of networks (Coburn et al., 2010, p35).

In evaluating a relatively ambitious project to promote PL through between-school NLCs in England, Sammons et al. (2007) concluded that the teachers involved reported little impact on pupil outcomes but that these teachers self-reported generally favourable impacts in terms of their engagement with PL. However, there was significant variation dependant on differing degrees of autonomy, commitment and capacity and those in more senior leadership positions tended to have the most positive perceptions of the impact of the NLCs.

From a project setting up networks of rural schools in the Pacific Northwest, Hargreaves, Parsley and Cox (2015) identify the following lessons:

- There is no shortcut for establishing a shared vision and goals for the network
- Recruitment to the network is highly dependent on personal communication and trusting relationships
- Participants should share some key commonalities
- Resources matter, especially for travel and release time for meetings
- Ample opportunities for 'like' participants to collaborate should be provided
- Network activities should be structured for high-quality collaboration
- Leaders should steer and disturb, not direct or disown.

They also highlight that these networks worked with the support of an organisation to attend to tasks such as facilitation and logistics and were enhanced by working in partnership with KOs with critical enquiry skills. Although these networks were initially instigated by system leaders it was decided the purpose having maximum impact was to connect and encourage collaboration between teachers of the same grade or subject in small, rural schools. The opportunity to work with colleagues from a similar context with the same issues were highly valued by the participants, although not all the groups were able to identify a focus for their work quickly.

A system-wide attempt to develop in-school PLCs which subsequently led to some between-school NLCs in Taiwan is described by Chen (2018). Historically the culture had been one of teacher isolation but in order to stimulate and support curriculum innovation a programme of PLCs was developed, although subsequent research showed that despite increased collaboration few schools developed the conditions necessary for effective PLCs. However, from this grew the desire of some teachers to develop teacher-led between-school NLCs defined as "*a networked community with educators who share common vision and values and build lateral capacity to generate collective efforts that enhance teaching and learning for all*" (Chen, 2018, p160). There was government support for some teachers to make study visits to other countries and to undertake leadership training but teachers formed the NLCs on a voluntary and informal manner often meeting in coffee shops and using social media to communicate. It can be seen that these NLCs largely came about and were sustained by the vision and enthusiasm of the member teachers but this was facilitated by some support from leaders within the education system, or at the very least they did not prevent the teachers from developing the NLCs. Chen reports that it too early to tell whether the NLCs will be sustained due to ongoing innovation, unstable government support, conflict with school-based PLCs, or lack of validation (Chen, 2018, p168). Chen's account raises the issues of how

independent from existing education system structures effective between-school networks can be, and the role of schools and LAs in supporting them.

A need to better define the role of LAs in '*leading from the middle*' has been prominent in recent reports on Scottish education (Hargreaves et al., 2015, p111; ICEA, 2018, p33), perhaps unsurprisingly given the research interests of several of the authors. The role of middle leaders in schools, Principal Teachers (PT) in Scotland, have a similarly important role between school senior leadership teams (SLT) and classroom teachers. They are central in leading teaching, learning and PL in a subject domain where they play a pivotal role in influencing teachers' classroom practice and securing better outcomes for pupils (Harris & Jones, 2017). In both cases the importance of aligning vision and priorities at the same time as reducing tensions between expectations from above and below are important so that there is a clear and consistent narrative which allows a culture of professional empowerment, responsibility, and ownership leading to high levels of teacher agency. Central to this is the development in teachers of trust in the leadership in schools and LAs (Adams & Miskell, 2016; Bryk & Schneider, 2003). If this is achieved then the conditions may be right to allow the development and sustaining of collaborative NLCs which can build capacity in individual teachers and the system as a whole.

4. Research Questions

There are therefore a number of issues arising from the literature which may impact on the effectiveness of PL for teachers of physics in schools across the north-east of Scotland. Learning from the literature, I did not wish to impose an intervention on teachers, or to decrease their agency, therefore I decided to conduct an exploratory study to better understand the particular contexts, opportunities and constraints for PL and collaboration for

teachers of physics across the region using focus groups to gather data. In order to help shape the intervention phase of the study it was important to determine the teachers' current needs and goals as well as their aspirations for the future. This resulted in a more in-depth study of a NLC of physics teachers in a relatively remote area of the north of Scotland during which PL was organised to help provide for their needs.

The initial research questions (RQ) for the focus group part of the study were informed by previous work undertaken in Scotland by Kennedy (2011) and designed both to establish baseline data as well as look to the second phase of the study.

1. What PL opportunities and resources do teachers perceive are available to them, and which are most valued by them?
2. What are the key issues that facilitate and/or constrain PL and aspirations for future PL?

The intervention phase of the study added to the findings from the focus group study but also focussed on the following questions:

3. How well does a NLC promote collaborative, enquiry-based PL of physics teachers across a LA?
4. How well does a NLC provide access to appropriate KOs for its teachers?
5. What leadership and facilitation are needed to ensure an effective and sustainable NLC?

As described in Robson and McCartan (2016, p60) the significance of the different RQs evolved as the study proceeded.

5. Methodology

5.1 Focus group phase – RQ1 and RQ2

I have supported teachers in my IOP Network area since 2003 and have developed significant knowledge and symbolic capital (Bourdieu, 1977) as a result. However, in the first stage of this study, in order to answer RQ1 and RQ2, improve my knowledge of the needs and goals of the teachers, and therefore better shape support going forwards, I conducted six focus groups involving 26 teachers from 6 schools across 4 LAs, see Appendix 1. Focus groups were chosen because they can provide high-quality, nuanced data with opportunities to follow up issues raised by the semi-structured questions (Drever, 1995, p2). The interactions between the group members were also expected to help identify significant issues and common themes (Cohen et al., 2000, p288) and to provide richer and deeper discussions than would likely be the case during interviews with individuals (Robson & McCartan, 2016, p299). It was also hoped this process would help build relationships, give some ownership of the process to those involved, and improve buy-in for any subsequent intervention. The sample was partly one of convenience for geographical reasons. It was chosen to give a range of schools across the LAs to help identify generic issues as well as ones which might be LA-specific. In all schools, teachers had a history of engaging with PL activities. Contact with each school was made through a teacher who was well known to me and who had engaged with PL activities previously. Therefore this is likely to be a '*best-case*' sample consisting of teachers relatively well engaged with PL. They were also likely to have given greater consideration to the issues than less engaged teachers. Questions designed to explore RQ1 and RQ2 (Appendix 2) were sent to the teachers a few days in advance of the meetings to allow them to give the questions some thought before the group interviews. Following ethics guidelines (BERA, 2011, p5), all teachers were provided with information describing the purposes and nature of the study and

completed a consent form. Confidentiality was guaranteed and it was hoped that this would help ensure engagement and honest answers.

Extensive detailed notes were taken at each of the focus groups. The focus groups were audio recorded to allow the notes to be checked if required. For reasons of time, full transcripts of the recordings were not made but the notes relating to each question from each focus group were collated, summarised and typed. Using a grounded, inductive approach (Robson & McCartan, 2016, p161), recurring themes were then highlighted and this information collated once more as the emerging themes became more visible. Most issues applied to teachers in all focus groups and in all LAs but there were some that were more specific to particular groups.

5.2 Intervention phase – RQ3, RQ4, and RQ5

5.2.1 Deciding on who to include in the intervention

Similar needs, goals and barriers were evident for most of the groups interviewed. As issues of geography and finance are always going to restrict teachers in remote areas travelling elsewhere for PL the focus for the study had to be on facilitating effective PL and access to KOs in their local area, arguably the raison d'être of the IOP Network. The physics teachers in one LA presented themselves as a good and opportune group to study further. These teachers had a long tradition of holding meetings several times per year at a central location within a 40 minute drive for everyone. The LA had supported one or two subject-based in-service days per year when all physics teachers could meet plus afternoon meetings for one representative per school, usually a PT, four times per year. In my role as IOP PNC I had organised twilight PL sessions, open to all teachers in the LA and beyond, which conveniently followed on from around three of these meeting per year: the PTs forming a core of the audience for these. As a

result there was a history of co-operation, communication, trust and respect between the teachers, especially the PTs. However, the LA had decided to stop the afternoon meetings, which disrupted the arrangement for the follow-on twilight meetings, and also reduced the in-service time for the physics teachers to meet to one afternoon. This gave me an opportunity to investigate the issues around sustaining this NLC of physics teachers when there was much-reduced LA support but continued IOP support.

5.2.2. The nature of the intervention

The LA consists of eight secondary schools employing a total of 17 physics teachers, equal to around 15 full-time equivalent teachers. I was able to speak to 16 of them during their in-service meeting, which was held shortly after the focus groups, and explain my proposals for continued IOP support and this study. It was hoped that this face-to-face engagement between the researcher and those teachers involved in the study would improve participation rates as they were given an opportunity to ask questions, have queries answered, and to be given reassurances. The design of the intervention built on positive findings from the focus groups and existing valued practice, and included several meetings addressing PL issues identified by, or agreed with, the teachers and which were deliverable within resource constraints (see Appendix 3). In order to gather some base-line data beyond that already gathered in the focus groups, and which was more specific to this NLC, a questionnaire (Appendix 4) was sent to all teachers.

5.2.3 Data collection methods to answer RQ3, RQ4 and RQ5

Towards the end of the school year, after the intervention was complete, and to answer the RQs, a multi-strategy data collection approach (Robson & McCartan, 2016, p174) was used with a follow-up questionnaire (Appendix 5) sent to all teachers, visits made to five of the

schools to interview eight of the teachers, as well as notes and reflections made during and after the NLC meetings and meetings with two LA Officers which provided wider contextual data. This generated both quantitative and qualitative data. A semi-structured interview schedule (Appendix 6) was sent to those interviewed a few days in advance of the interviews as had been the case for the initial focus groups. The interview subjects chosen were: the two schools in the LA which were in the original focus group sample; a school having only one physics teacher; the school with the most experienced teacher who had also contributed most to the content of the NLC meetings and had been the only teacher to attend all six meetings, and the school where there were only relatively inexperienced teachers with no PT Physics, only a Head of Science Faculty who was not a physics teacher. As interviews were conducted with almost half of the entire study group and included teachers from the full range of experience and contexts it can be considered a representative sample which could be cross-referenced with the data from the questionnaires. I would have liked to have conducted interviews with more of the teachers but finding mutually agreeable times was problematic, a disadvantage of interviews (Drever, 1995, p3).

Using questionnaires and semi-structured interviews allowed for some cross-checking across the sample with the questionnaires able to relatively quickly gather basic descriptive data (Munn & Drever, 1990, p5) but the interviews able to explore issues in more subtle detail with the interviewer able to prompt interviewees to clarify answers (Cohen et al., 2000, p269).

There were limitations to the data available from the questionnaires. The return rate of fully completed questionnaires, both pre- and post-intervention, was only about 65%. A few additional respondents returning partially completed forms or reasons for non-completion, which at least provided some information regarding the barriers to participation in activities. For both questionnaires this included returns from all seven PTs, plus the 'lead' teacher in the eighth school, but a significantly lower return rate from the unpromoted teachers in the

schools. This gives a bias towards the more senior, and more experienced, teachers in the LA, and was a reason I ensured I included interviews in the school with the least experienced teachers. In order to try to increase the response rate for the post-intervention questionnaire greater use was made of dichotomous, multiple-choice or rating-scale questions with fewer open questions. This resulted in the questionnaire being quicker to complete whilst still allowing for extended responses if the teacher desired (Cohen et al., 2000, p248). The lack of response from the more junior teachers could have been influenced by issues such as confidentiality, anonymity, traceability, beneficence, maleficence, and sensitivity (Cohen et al., 2000, p246) despite assurance that all data would be treated in confidence and anonymity maintained in any reports or publications resulting from the study. Those in more senior positions may well have seen taking part in the study as having greater relevance or greater potential to improve their situation.

The data from the questionnaires were collated using frequency distributions for the multiple-choice and rating-scale questions and a gathering of information under the question sections for the more open questions. This information was then grouped and summarised around the RQs, the main themes emerging from the data, and in relation to the literature. As the questionnaire sample was biased towards the PTs their responses were also analysed separately to the non-PTs to determine any significant differences.

For the interviews, as for the focus groups, extensive detailed notes were taken along with audio recordings to allow the notes and potential quotations to be checked if required. The responses to question were collated and typed. Recurring themes were then highlighted and this information summarised.

During the intervention I made notes during, and on reflection after, meetings and on one occasion my supervisor provided notes when visiting one of the meetings as an observer.

These helped inform the collation and summarising of the data collected by the questionnaires and interviews.

In my IOP PNC role I was well known to most of the teachers involved in the intervention as well as being the researcher and a KO responsible for presenting and facilitating much of the PL which raises a potential ethical conflict. I tried to ensure honest responses were obtained, through both questionnaires and interviews, by ensuring anonymity and trying to build trusting and respectful relationships. The fact that some critical responses were made provides at least some evidence that not all were just responding in the way they thought I wished to hear.

6. Findings

The findings are structured around the key themes emerging from the data. Section 6.1 addresses themes emerging from the focus groups and addressing RQ1 and RQ2. Here 6.1.1-6.1.4 address RQ1 and 6.1.5-6.1.6 address RQ2. Section 6.2 adds some additional pre-intervention responses to RQ1 and RQ2. Section 6.3 addresses the post-intervention data with 6.3.1 addressing RQ3, 6.3.2 addressing RQ4, and 6.3.3 addressing RQ5. Section 6.3.4 addresses the key theme of developing and sustaining a NLC.

6.1 Initial focus groups

All teachers were positively disposed towards PL, which is perhaps not surprising given the criteria used for selecting the sample. All teachers thought there were many opportunities for PL. This was available from many different sources and all of the following were mentioned: learning from and with colleagues; PL sessions provided by schools - twilights, lunchtimes and

in-service days; LA provided sessions; university courses, including the Open University; Massive Open On-line Courses (MOOCs); Scottish Schools Education Research Centre (SSERC) courses; learned society and professional association events and conferences; subject-specific email fora and sharing websites; TeachMeets and Pedagoo events[1], and events provided by SQA on curriculum and assessment changes. It was clear that in answer to RQ1, teachers perceive that a wide range of PL opportunities are available to them.

6.1.1 Working with departmental colleagues – RQ1

All teachers interviewed identified their departmental colleagues as a significant source of PL. All acknowledged the value of being able to draw on the support of colleagues with different science backgrounds when preparing for teaching outside their specialism in the Broad General Education (BGE)[2] phase of the curriculum and when setting up apparatus for practical work. This was clearly the most significant source of teacher learning in all schools visited and was valued highly by all. It consisted of discussion and questioning in both formal and informal meetings and through observation.

All teachers reported informal learning with colleagues, during non-teaching periods, at breaks, lunchtime and before or after the timetabled school day, and opportunities for doing this were recognised as important.

All schools had some form of periodic Departmental Meeting (DM) or Faculty Meeting (FM) arrangement which met at different frequencies from weekly to termly. It was considered that these provided an opportunity to share good practice, but many acknowledged that time was often spent on administrative business rather than on teaching and learning or teacher PL. Some schools also organised twilight or lunchtime PL sessions and made use of time made available on in-service days for sharing best practice and discussing teaching and learning.

In all schools collaboration between teachers across science was strong in the BGE phase with specialists frequently assisting their non-specialist colleagues, particularly when developing new courses and with practical work. Many indicated they learned by watching colleagues and then trying things out for themselves.

It was acknowledged that the level of collaboration depended on the ethos and management of the collaborative group. Some were said to work well, others less so. It was widely acknowledged that a group of people cannot be told to go to a room together and collaborate, but that a clear common goal and some leadership of the group is required.

The importance and value teachers placed on being able to work collaboratively with colleagues in their own schools, at subject and more generic levels, and with subject staff from other local schools was very apparent. Teachers saw their colleagues as a very significant and accessible source of professional advice and support but indicated they needed more time, both formally and informally, to discuss the development of teaching and learning in their context. This was particularly significant due to the high levels of curriculum and assessment changes taking place in the system which is adding significant pressures on teacher workload and time.

Not all PL in departments was seen as having a collaborative element. Many teachers made reference to '*learning by doing*' and using an ongoing process of self-evaluation, reflection on lessons and refining future practice as a result.

6.1.2 PL within schools – RQ1

While the support from immediate departmental colleagues was widely valued and welcomed, whole-school opportunities gained a more mixed response from teachers. All focus groups

indicated that there was a lot of expertise within their schools but this was not always identified and opportunities to share this expertise were often limited. A few indicated that Headteachers and SLTs were valuable in identifying staff in schools who had useful expertise to share.

Teachers commented on a lack of clear vision and direction within schools regarding PL and in-school provision. They stated there often appeared to be a '*hidden agenda*', perhaps not intentionally but the purpose and vision was not communicated effectively. Often there were too many competing demands, initiatives or activities done once and not revisited or consolidated. Some commented that SLT members studying for Headship or Masters level courses conducted projects for these courses but once they had their qualification nothing more was done with the projects or the outcomes.

Several schools organised a programme of PL sessions in the form of lunchtime or twilight workshops and these were generally viewed positively. However, time was a restriction on these, as well as child-care and similar issues for some staff. Some schools offered a wide range of options delivered by school staff, but these did not always run due to lack of uptake and the offer was generally the same for all teachers from recently qualified to experienced. Some commented on the fact that designing and delivering a PL session for colleagues was likely to be a more beneficial PL experience for the person delivering the session than for those attending.

Whole-school in-service day PL activities were generally rated poorly. Many commented on SLT members and LA staff being removed from the realities of teaching and presenting poorly organised sessions in a top-down fashion with little explanation of the rationale behind what they were doing, or opportunities for teachers to question or discuss this. Teachers therefore felt they were being told to do things without understanding why.

Teachers in schools in all LAs were, or had been, involved in some form of in school PLC or TLC, often facilitated by an external organisation, either directly or through a cascade model through some 'lead' staff members. These were generally seen as being a good idea but were often implemented badly and were not always sustained beyond being an initiative. Many of the TLCs had been initially set up on a voluntary basis, sometimes on a subject basis but more often involving cross-curricular groups of teachers. Frequently schools had then decided that these groups were to become mandatory. Teachers reported that these groups being made mandatory decreased their usefulness and effectiveness as it changed the ethos and nature of participation. Teachers reported that to be effective TLCs needed to be well led and to have a clear rationale, focus and purpose. Whilst some TLCs were well led and facilitated, many reported that better facilitation and better input from appropriate KOs were required. Staff in one school in particular were very positive about the principles of the TLC work with which they were engaged, particularly its focus on collaborative enquiry and using research in the classroom. However, they thought they lacked good input from KOs to move their own PL and practice forward. They considered the support from the commercial organisation facilitating the TLCs poor and also rated their experiences of inputs from university staff poorly considering them lacking in an appreciation of the interplay between theory and practice in their context. In addition to TLCs some staff met with colleagues in other school working groups but it was recognised that their purpose was different to TLCs and they were not necessarily PL groups as they had a more administrative function.

6.1.3 Between-school PL in local authorities – RQ1

Centrally provided LA support was generally seen as not meeting teachers' needs well. For example, when commenting about a large centrally organised LA Learning Festival one teacher said:

"*[The Learning Festival was] as much use as a hole in the head. We were told to go but it was the biggest waste of my time and not appropriate for our needs at the time.*" T1

LA subject networks were seen by most as important opportunities for collaborative between-school working and all LAs currently or recently had some sort of subject network in place, although usually for only one representative from each school. Teachers in all LAs did not think these meetings operated effectively. Many saw them as good opportunities to share resources and compare progress between schools. Others saw them as largely ineffective as nothing more than this was achieved. The effectiveness of LA subject networks was seen to be compromised by there being a lack of leadership, support, time for meeting and group administration, and there being too little focus on teaching and learning but too much on administrative issues and accountability agendas dictated by the LA. In one of the LAs the subject network had ceased to function due to no-one being prepared to take on its leadership on what was seen to be a close to voluntary basis. Too often network meetings were seen only as opportunities for teachers to share surface details of their work, such as progress with new curricular changes, rather than to discuss and work on deeper teaching and learning matters, or worse still little more than opportunities for teachers to vent their frustrations with the demands put upon them. Teachers wished to see effective and impactful LA subject networks with good organisation with a strong focus on teaching and learning.

Opportunities for all physics teachers in a LA to meet together on some in-service days were welcomed but these meetings suffered from similar problems as the network meetings.

Teachers in all LAs considered that information on available PL within the LA could be communicated more effectively and that online booking and recording systems were cumbersome. It was considered that it should be easy for LAs to provide venues for groups to

meet, both formally and informally. However, it was seen as important that such meetings had good leadership and were sufficiently outcomes focussed.

The LAs and Education Scotland, which is both the national inspection and support agency, retain a relationship which has a quality assurance and accountability element as well as a supportive PL one with schools and teachers. A teacher commented:

> "*It feels like there is 'Big Brother' even if there is no-one actually watching, and this is not an appropriate manner to treat professionals.*" T2

Teachers in some of the focus groups indicated they had very little direct contact with LA central staff, did not know their remits, did not know if there was anyone tasked with supporting their PL, and doubted the capacity of the LA to provide such support, especially in subject-specific matters.

6.1.4 Support from KOs – RQ1

Having subject specialist teachers in all three sciences within school science faculties was seen to be important as they can act as KOs for teachers working outside their own specialist area. A range of other KOs were acknowledged to exist within schools, such as an excellent librarian mentioned by staff in one school.

SSERC and IOP staff were widely acknowledged to be KOs and their high quality, subject-specific advice appreciated. This is in direct contrast with the consultants that Tytler et al. (2011, p875) mention whose input was valued in some cases but often not sustained through follow-up activities. They were also accessible remotely via subject email fora and by direct emails. The fact that many SSERC and IOP workshops integrated new approaches to practical

work with relevant SMK and PCK, and also provided some of the equipment needed to teach the topics on returning to school, was greatly valued.

Teachers in most schools talked positively about the use of subject email fora as a means of helping teachers communicate with each other and to provide help and advice to each other in a manner where hierarchies and other barriers are diminished, although some mentioned these provided a means for some to '*share ignorance*'. Both SSERC and Learned Societies were seen to have been invaluable in helping improve communication, bringing people together and providing shared resources.

Some schools had developed good industry links bringing teachers into contact with KOs from business and industry.

Support from university sources received a more mixed response. Teachers mentioned contact with KOs from universities, either when Initial Teacher Education (ITE) students were placed in their school, or for a small number of teachers when undertaking leadership, Masters or Doctoral studies. Some were very positive about MOOC and Open University courses for developing SMK. However, leadership and more generic education courses received a mixed response with some positive but several very negative responses that what had been studied was not particularly relevant to their context. One group was particularly scathing about university staff being out of touch with classroom realities.

Generally teachers did not think they had good access to KOs in more general pedagogical matters. There was dissatisfaction with the commercial support available to some TLCs and the frequently used cascade method of disseminating PL was considered not to work. Within schools some Headteachers and Deputes were considered to assist teachers access KOs in other curricular areas in their school but this was not the case in all schools. Some considered

that Education Scotland could play a more significant role in identifying, communicating and sharing best practice.

6.1.5 Remoteness and rurality – RQ2

All schools included in the sample are 100 to 250 minutes[3] by car north of the main population centres in the Central Belt of Scotland. Not all were in rural areas but remoteness from the main population centres where '*most things happen*' was a consistent issue and obviously considered by many to be a constraint on their PL.

Access to relevant PL courses was seen to be an issue, especially for teachers in more remote and rural areas. There many teachers commented on events not being available locally but only in the Central Belt which therefore involved travel and accommodation, putting further pressure on budgets and supply teacher cover, which was already in short supply. Although teachers thought that SSERC provided excellent support for science practical work and health and safety, access to its base in the Central Belt was seen as an issue for those in more remote schools. It was appreciated, and commented upon favourably, that many SSERC courses came with funding schemes to assist with costs.

6.1.6 Barriers to effective PL – RQ2

In summary the (interrelated) barriers to effective PL were:

- Lack of time
- Excessive workload
- Lack of appropriate access to PL in more remote areas
- Insufficient funding
- Lack of opportunity for choice or influence of PL provision

- Lack of PL leadership, facilitation or co-ordination within and between schools.

Perhaps unsurprisingly the overwhelming response to asking what barriers prevented effective PL was '*lack of time*', very closely followed by the related issue of '*workload*'. Teachers in all schools complained about not having enough non-contact time, once other demands were acted upon, or insufficient non-contact time in common between teachers to facilitate meetings and collaborative working. Teachers wished to consider, reflect on, and to discuss with colleagues the processes of teaching and learning. Staff shortages in many subjects and areas were seen to be making this increasingly difficult. Time for teachers to discuss teaching and learning together and share professional knowledge and experiences was recognised as improving not only PL but also teacher morale.

Initiative overload was frequently identified and teachers wished to see developments be given enough time to properly bed-in, be evaluated and those having impact be supported on a sustainable basis, rather than drop down the priority list only to be replaced with other initiatives which further increased workload and reduced time for effective PL focussed on improving teaching and learning.

The importance and value teachers placed on being able to work collaboratively with colleagues in their own schools, at subject and more generic levels, and with subject staff from other local schools were very apparent. Teachers saw their colleagues as a very significant and accessible source of professional advice and support but indicated they needed more time, both formally and informally, to discuss the development of teaching and learning in their context, particularly at times of curriculum and assessment change. The move from having a Head of Department in each of the three sciences to a Head of Faculty for science was seen to be a barrier to effective PL, particularly informal PL, as this reduced the likelihood of there

being an experienced teacher in each science subject in every school to act as a KO for other teachers.

Teachers frequently commented that when teachers were released or supported to attend external courses or conferences there was often insufficient time for them to share their learning with their colleagues, or to follow up and consolidate this thereafter. There was a '*dribble*' rather than a '*cascade*'. Restricted funding was also seen as being a significant barrier for many attending courses or taking part in PL. Often teachers were self-censoring, not asking for PL which they thought was likely to be refused due to lack of funding for course fees, accommodation, travel or supply teacher cover. Teachers in areas more remote from the Central Belt, where many events were perceived to occur, commented on how this problem was exacerbated owing to their additional travel and accommodation requirements.

Several teachers wished to conduct more peer observation, not just with colleagues in their own school but with recognised subject experts in other local schools. Teachers in all schools saw the need for a LA science officer/advisor who should be well placed to identify expertise and help co-ordinate, communicate and share this with others. Teachers also thought LA science officer/advisors would be well placed to help identify and communicate available PL opportunities, which at present were seen by many to be somewhat haphazard. The lack of a science officer/advisor in any of the LAs was seen to be a barrier to improving PL and more effective working of LA subject networks.

Accountability procedures for PL, both local in terms of schools and LAs and nationally in terms of the GTCS and its five yearly Professional Update process (GTCS, n.d.-b), were seen to be inefficient and time consuming. This ironically resulting in time taken away from effective PL and also a disincentive for some to engage in PL. Although some saw the completion of

evaluation and Professional Update as a useful process for themselves, others saw it as a top down quality assurance process which was largely not acted upon.

Changes to the range of promoted posts in recent years were widely recognised as a disincentive for many to undertake PL. Many staff saw the removal of Chartered Teacher[4] (CT) as a retrograde step which disincentivised teachers wishing to develop, but who also wished to remain in the classroom, from undertaking PL to a Masters level, by removing an important source of extrinsic motivation. Similarly the removal of Assistant Head of Department (APT) and Head of Department (PT) posts in many schools was seen to be detrimental as the jump from being an unpromoted teacher to a Head of Faculty (HoF) was seen to be too large and resulted in the HoF post being one involving too much administration and insufficient opportunity to lead teaching and learning. This was seen to be a barrier to effective PL, particularly informal PL, as this reduced the likelihood of there being an experienced teacher in each science subject in every school to act as a KO for other teachers. Having subject leadership more distributed across APT and PT posts was considered to better allow teachers to focus on the leadership of teaching and learning as well as complete the inevitable administration involved.

Many teachers commented on the provision of PL being disjointed, perhaps an indication of too much PL being delivered to or at teachers from above. Many also commented on the lack of consultation and choice in the use of school in-service days and the lack of explanation or a rationale being given for the PL provided on such occasions. Teachers commented on much of the PL provided for them resulting in the feeling of bouncing from one initiative to the next with little or no opportunity for consolidation or for an opportunity to evaluate whether the PL actually met teachers' needs.

Whether schools, faculties or departments were seen to operate as effective PLCs depended on the ethos of the school and the relationships between the teachers involved, and while this was good in some schools and departments it was less so in others.

After the focus groups it was decided to conduct an intervention focussed on supporting the continuation of the NLC in one LA where the LA support for the NLC had been reduced, see Appendix 3 for the timeline of the study. As this involved working with a pre-existing group that was beyond the '*starter*' phase of learning community development as described by Bolam et al. (2005, p147), it was hoped this would allow progress with the more advanced aspects of the study, such as developing enquiry-based approaches and teacher agency, during the relatively short timescale of the intervention.

6.2 Pre-intervention questionnaire

As described above, having decided on the focus of the intervention of this study a questionnaire (Appendix 4) was sent to the 17 physics teachers in that LA in order to gather some further base-line data specific to their context. Completed questionnaires were received from 11 teachers with another stating that time and workload pressures prevented completion. Of the eleven, six stated that they frequently attended the previous LA-organised meetings for PTs, four attending occasionally and only one never attending.

6.2.1 LA PTs meetings – RQ1

These meetings were clearly appreciated and valued by all staff, even for those who had only occasionally or never attended. Meetings were seen to have a positive, relaxed ethos which

promoted sharing and dialogue, and to be supportive for staff new in post. Their discontinuation by the LA was clearly causing frustrations:

> "*I definitely feel less supported and less valued as a teacher by my employer than in the past when there were more opportunities for collaboration and professional learning*."
> T3

Teachers strongly considered these meetings to have been well focussed on teaching and learning and to have helped to facilitate a PLC of physics teachers, and through the PTs support all physics teachers in the LA. Despite the teachers thinking that the meetings helped facilitate them working as a PLC, in my professional opinion, their mode of working would not meet fully the criteria for effective PLC as described by Stoll et al. (2006, p226).

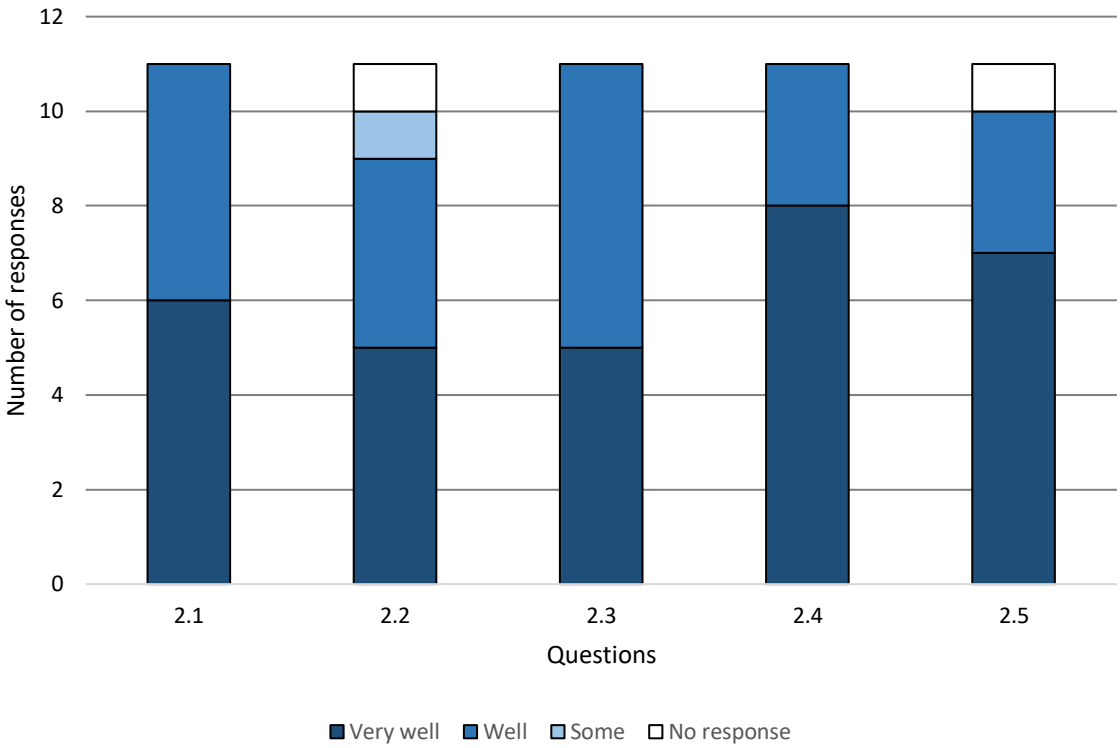
6.2.2 Twilight PL sessions – RQ1

It was clear that the IOP-supported twilight PL sessions were very highly valued by teachers. Providing access to KOs and the informal discussion, both during and at the optional meal after the meetings, were rated highly. However, the sessions were less good at meeting the needs of different teachers such as NQTs and PTs, see Figure 2. That teachers were prepared to be critical on the questionnaire gave me some indication that their answers were honest and reflected their views.

6.2.3 Future working – RQ2

Teachers unanimously agreed that face-to-face subject-specific PL meetings were essential to the on-going support and development of physics teachers and effective teaching and learning of physics in their schools. Several teachers commented on the PL needs of teachers in small

schools, particularly ones where there is only one physics teacher or where there are new and inexperienced staff, and how meetings of physics teachers from across the LA allowed the sharing of the knowledge of experienced staff for the benefit of all.



Key to questions:

2.1 How well do these sessions support your physics PL needs?

2.2 How well do you think these sessions meet the needs of different teachers?

2.3 How well do these sessions help you share good practice or work collaboratively with other physics teachers?

2.4 How well do these sessions provide input and support from appropriate KOs?

2.5 How well do the informal discussions and networking, both during the sessions and the meals that follow, support your PL?

Figure 2: Teacher views of previous twilight IOP Teacher Network meetings.

Several teachers commented on the need to hold subject-specific PL events during normal working time rather than as twilights. This reflected pressures such as child-care which restrict the ability of some to attend meetings outside normal school hours. Others commented on

the importance of agreeing and setting agendas and a clear focus for the PL. This included ensuring an open and inclusive approach but one firmly rooted in the teachers setting their own priorities and showing agency.

The majority of teachers thought that some form of notes of meetings should be kept and circulated by email to all physics teachers in the LA. Many also thought that these should be sent to Headteachers and LA Officers. There were two strongly dissenting voices, both unpromoted teachers, who did not necessarily see the need for a formal written record and were concerned that the motivation to circulate a written record beyond the group was that of accountability rather than support.

Although the majority of the teachers indicated that face-to-face meetings are the best way of working, alternatives were suggested including visiting others' classes and more time for individuals to undertake PL on their own, the outcomes of which could then be shared at meetings. Some thought it would be appropriate to hold more frequent meetings and for more inexperienced staff to work closely with more experienced colleagues implying some form of mentoring arrangement. One teacher stated strongly that there should not be an expectation that PL should take place in teacher's own time such as the weekend or require significant travel. In other words, there is an entitlement that employers facilitate effective PL for teachers within their contractual arrangements. This was echoed by another comment:

> "*I never cease to be amazed by the irony that in education less value seems to be placed on the training and development of teachers than in any other profession I can think of*." T4

However, there was also the positive comment:

"*The Physics Group works very well in [this LA], we are all happy to share what we have amongst ourselves, happy to loan equipment for AH work, share resources. I feel, as a group, we work very well together*." T5

Information from the questionnaire was used to help shape the intervention programme (Appendix 3) as described in section 5.2.2.

6.3 Post-intervention questionnaire and interviews

Completed questionnaires were received from 10 teachers with minimally completed responses from another three. As with the previous questionnaire full responses were received from the PT or 'lead' teacher in all eight schools. Interviews were conducted with eight teachers, four PTs and four unpromoted teachers, across five of the eight schools in the LA.

Overall the teachers returning questionnaires attended 2.8 of the 6 NLC meetings. However, this average masks a significant bias with the PTs attending on average 4.1, one PT attending all 6. The unpromoted teachers attended on average 1.0. From attendance records, three of the seventeen teachers in the LA did not attend any of the NLC meetings. Several NLC meetings attracted teachers from neighbouring LAs with one attracting eight teachers, including four PTs, from within the LA and seven from outside. Meetings provided opportunities for sharing more widely than the immediate NLC group.

Several teachers expressed regret that they had not been able to attend more of the NLC twilight meetings, the most frequent reason given being family commitments which was a significant barrier for many of the mainly younger, more junior staff.

The responses from the teachers who had attended meetings were very positive, similar to the pre-intervention responses shown in Figure 2, exemplified by:

> "*The Network has been absolutely essential. If it were not for the IOP Network we would be bereft of any local physics CPD*." T6

> "*Looking across my calendar for the year there is very little I have missed that I have worried about but the twilight meetings are the thing that has really stood out, and I am all the poorer for missing some meetings*." T7

Frequency distributions for the rating-scale questions are shown in Appendix 7.

6.3.1 Collaborative and enquiry-based PL – RQ3

Although the meetings were valued, analysis of the questionnaires and interviews showed that they had led to only a limited amount of collaborative working between meetings. The communication which had occurred between meetings was generally limited to teachers emailing each other to seek advice or resources related to something that had been spoken about at a face-to-face meeting. Much of the communication was between people working in proximity to each other or who already had an established relationship. Figure 3 illustrates the connections between teachers reported in the questionnaires. Several of the PTs play a key role in communications. Two other teachers also have significant connections in the network: the longest serving of the teachers in the school without a PT physics, and a teacher who has a particular interest in PL.

Discussions at meetings had led to the inclusion of related or extension work at future meetings but not in a particularly strategic manner. Some commented on the need for face-

to-face meetings to build relationships and the need for consistency of attendance in order to develop more systematic collaborative working. Whilst those interviewed all thought the meetings valuable this was very much at the more basic level of a simple discourse community rather than exhibiting the more rigorous features of a PLC. For example:

"*It is good to have a chance to have a blether*." T8

Although there were some signs of progress:

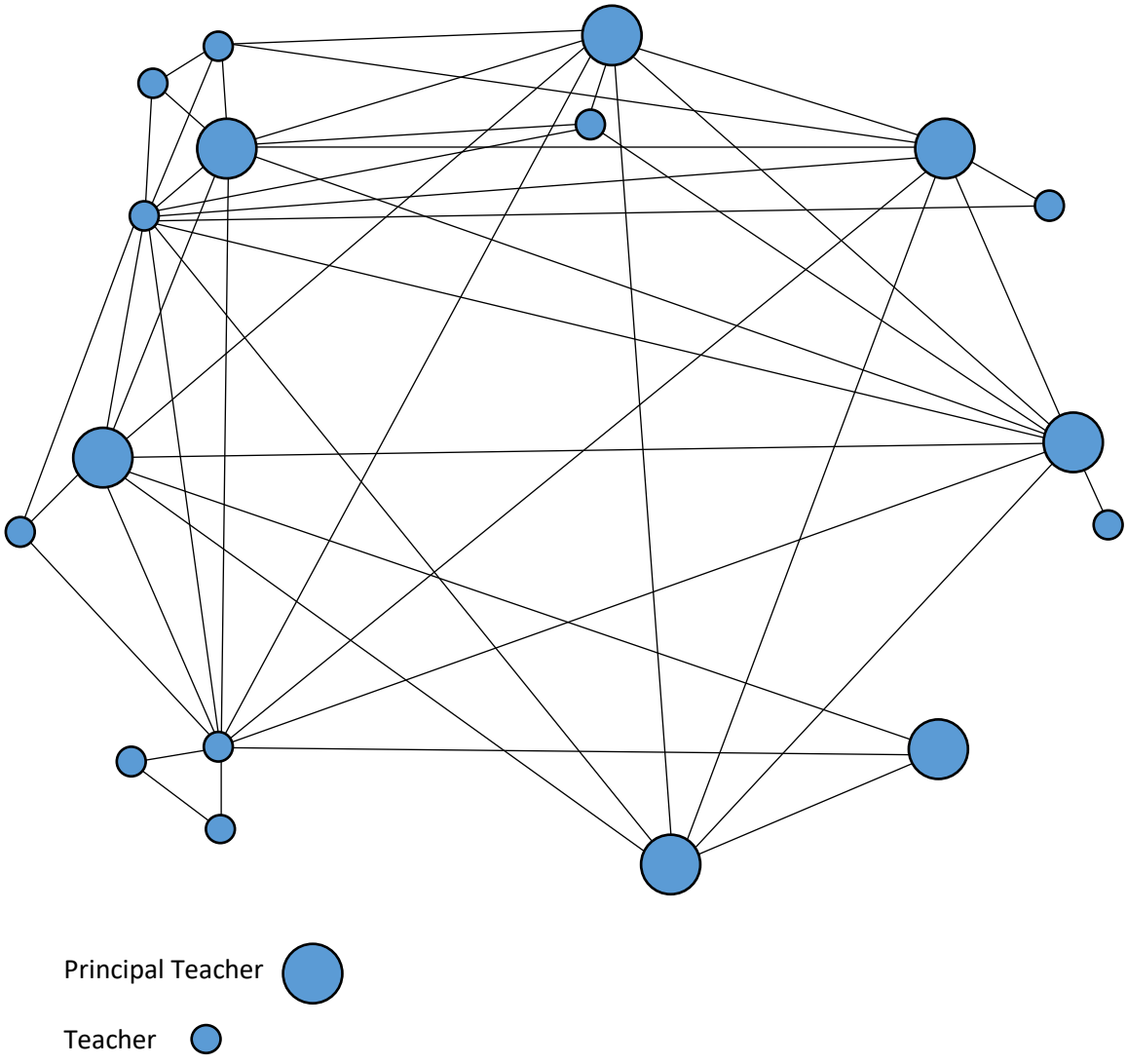


Figure 3: Self-reported connections between teachers in the NLC.

"*The network has gone beyond just being a group of people who know each other. It is facilitated by the 'stronger members' of the group. The meetings can be a catalyst for making things happen, or me getting round to doing things sooner*." T7

There was no evidence of the NLC meetings having stimulated teacher enquiry. Indeed several interviewees did not understand the term despite it being included in the GTCS Standards for Registration as a teacher in Scotland (GTCS, 2012b). There was an acknowledgement by some that the development of teacher enquiry was important as part of PD, something to be focussed on in the future and that the NLC meetings had helped move teachers towards this:

"*The Network has not moved on to enquiry yet but the Network is establishing a bedrock on which enquiry might happen. Enquiry is the next step, we are not there yet. Sessions like the one on Diagnostic Questions have been good and I would like to work with others on things like this but everyone is busy*." T8

All considered the meetings to be focussed on pupil learning and this was clearly thought to be a strength of PL with a subject focus.

6.3.2 Access to KOs – RQ4

Access to suitable KOs was seen by all to be very important and the support from IOP in helping organise the input from KOs was welcomed and appreciated.

The difficulties faced getting access to KOs in remote communities was acknowledged:

"*Getting KO input here is always geographically challenging. Remoteness is a particular issue affecting us here*." T8

"*There are things advertised in the Central Belt that I would like to attend but I wouldn't even think about due to the cost and the effort getting there*." T9

"*If I consider what points of contact I would have if it were not for the IOP meetings I would only really have Sputnik [IOP email forum for Scottish physics teachers], which is useful but it is very much about sifting the wheat from the chaff. Other than that it would be very limited, I would be struggling. There is not another source that would give me the sort of support we get from the IOP and from the Network*." T7

It is clear that, especially in a remote community, the NLC meetings provided the main, if not only, face-to-face input of subject-specific KO support for many of the teachers. This included support from KOs external to the group but also sharing of expertise from KOs within the group itself. The need for input from KOs from outside the group was acknowledged and appreciated.

"*It is good to have someone neutral to the local authority context to draw us out from being stuck in our own local authority context*." T2

6.3.3 Leadership and facilitation for an effective and sustainable NLC – RQ5

Whilst one of the PTs in the NLC took on a leadership role for the subject group which had met previously this was done with no additional time allocation, remuneration or administrative support. This role had previously rotated around the group annually. With the demise of the group the current incumbent continued in the role, personally seeing it important that someone do so, and that many benefits came from having continued communication between the physics teachers in the LA. Leading the NLC was seen to be difficult for a teacher with a

full-time teaching commitment and the support of the IOP PNC was seen as significant in helping keep the NLC going through the year:

> "*It would be a lot more likely for the Network to be sustainable if it was somebody's job to organise it*." T4

As well as gathering the views of the members of the NLC and co-ordinating agendas, leadership was seen to be important for disseminating knowledge amongst the NLC, such as sharing knowledge gained when someone attended an external PL event. It was acknowledged that this was not always an easy role for someone to undertake and requires a good level of authority and commitment:

> "*It needs someone to take the lead and the person needs to be quite forceful in making things happen*." T10

There were general concerns about the level of support from senior leaders in the LA and in schools, although this varied greatly between schools. A typical response was:

> "*No-one [in the LA] has an official role to oversee things related to physics education. I am concerned by the lack of support from the local authority, even within the school. There is a lack of acknowledgement of what we are doing and learning as a subject group*." T2

However, a teacher for one of the schools was very much more positive in relation to the senior leaders in that school:

"*Senior Management are aware of the benefits of the Network and support subject groups. They let people out to attend them. They recognise the absence of subject groups as detrimental to subject teaching. They also recognise that in physics we have well organised back-up from IOP*." T6

There was also recognition that although the IOP PNC provided significant support it was up to the teachers in the NLC to shape their own activities: a sign of some agency being demonstrated:

"*We need to discuss how best to support ourselves. It is good to have the IOP support but we need to ensure the Network can organise itself*." T10

It was also proposed that the full impact of the removal of the PT meetings had not yet been felt by the NLC:

"*It will probably be a while before we actually feel the pain of not having the PT meetings. We wouldn't necessarily feel it in the first year*." T7

"[The twilights] this year have been a more positive experience [than previous years] but they have been shaped by the PT meetings in the past." T2

This leads to how the NLC might be best developed.

6.3.4 Developing an effective and sustainable NLC

A major issue for developing and sustaining the NLC is access to the meetings. The timing of the twilights was a problem for some, but preferred by others. Several teachers in the NLC,

even some of the most keen and enthusiastic, had great difficulty attending twilight meetings, mainly due to child-care, an issue identified internationally by the OECD (2014, p112). Others preferred having twilight meetings as this meant they did not need to miss teaching their classes or to set cover work for classes which were rarely taught by another physics teacher in their absence. Some teachers pointed out that teachers are contracted for 35 hours per week although the timetabled school week is only 27.5 hours and teachers are expected to undertake PL activities during some of the additional hours. It is therefore not an unreasonable expectation that teachers attend occasional twilights and as commented on by one teacher:

> "*We need to do PL in our own time for our PRD [Professional Review and Development] and a programme of twilights like this fulfils that fairly well*." T8

An aspect of the recently changed meeting pattern was that often not all schools were represented at the twilights, whereas previously for the afternoon meeting of PTs it was normal for someone from every school to be present, with support from the LA and their school's SLT. However, PTs had not always communicated effectively with their other school colleagues. With the twilights the discussions and experiences gained were not shared by teachers from all schools in the LA as had occurred with the afternoon meetings. The fact that not everyone could attend the twilights was seen to diminish them compared to meetings held during the working school day with attendance expected by their school and LA leadership:

> "*Meeting in your own time makes it difficult for some to attend. Whilst the meetings have been very good because not everyone can attend they have not been as useful as they could have been*." T10

However, the previous arrangement of afternoon meetings was seen as not necessarily meeting the needs of all teachers well:

> "*One of the problems of the old system of PT meetings was that some of the people who would most benefit from them, like NQTs, didn't attend. The IOP twilights are better for NQTs*." T10

The dilemma raised above is fundamentally caused by Scottish secondary teachers having one of the highest class-contact commitments in the world (OECD, 2017, p380). This is compounded by there being inadequate prioritisation of time for collaborative PL of the form exemplified by the NLC during the remaining time.

There was some reluctance, despite the twilight meetings being outside school working hours, for teachers to have meetings completely independent of the knowledge of school SLTs. It was suggested by one that it was important that teachers better engage with their school's SLT to ensure there was support from them for all teachers to attend NLC meetings.

Many suggestions were made as to how best to take the NLC forward, including planning further ahead, which might ease attendance issues. Although the IOP-supported twilights were seen very positively there was a universal desire to see the LA reinstate both the termly afternoon meetings for a representative from all schools as well as one, preferably two, subject-specific in-service days per year when it was expected that all physics teachers attend. This provision was seen to be a good arrangement to ensure all physics teachers could play an active role in the NLC and that there is a shared experience that cannot be obtained with the voluntary twilight meetings:

"*We need a balance of in and out of school time so everyone has an opportunity to benefit from the experience of learning. We need to make use of in-service time to meet for subject PL*." T2

"*It would be nice to have an annual [day] meeting for all physics teachers*." T9

The fact that subject-specific needs were not well recognised by leaders in the LA was a general concern:

"*We [the teachers in the NLC] do have a lot of autonomy but it would be nice to feel we have some support rather than feeling we are getting away with it in spite of the LA*." T4

"*The key part to me is that the physics CPD is going on despite the council [LA], despite our employers, and the bit that is lacking is their support. I don't buy the financial argument, none of this costs money, other than the time to allow us to do it*." T7

It was widely acknowledged that the central capacity of the LA was limited, which was confirmed during the interviews of two LA officers, with a small number of staff spread very thinly which does not allow a reasonable level of engagement at a subject level:

"*Very little happens centrally in the LA. Staff such as QIOs [Quality Improvement Officers] are spread so thinly they cannot focus on anything. The turnover of staff does not help as some things get repeated by successive staff. If the LA is really serious about STEM they need to provide support to teachers. It seems to have been given lip service. There is a new flavour every month and no follow-through. There is a lack of*

momentum and things keep going off at tangents. We need joined up thinking between teachers, head teachers, QIOs etc." T10

Given the lack of central support capacity a well organised and vibrant NLC was seen to be an effective mechanism to facilitate other PL activities. There was a desire on the part of several, especially in the smaller schools, to organise learning visits where teachers could visit colleagues in other schools in some form of peer-observation or lesson study arrangement. Time was seen to be a major barrier to this but it was thought that this could have a major impact and could be achieved if subject-specific PL was given sufficient priority.

The teachers enjoyed talking about and learning about teaching and learning in a physics context rather than a generic basis, and that the NLC meetings had both deepened the thinking of some and enthused many:

"*I really enjoyed the sessions on Diagnostic Questions and Cognitive Load Theory this year, getting back to talking about the basics with a physics bias rather than a generic bias. It has really stimulated me*." T3

It was clear from the comments of all teachers that the NLC was providing worthwhile PL for its members and satisfying a need not provided for elsewhere. However, it is clear that it is still very much a discourse community of physics teachers not yet meeting the criteria for it to be described as an effective PLC. Whilst it is effective in helping share best practice between its members and provide input from some KOs it is not yet quite ready to take this to the next step of engaging and sharing more structured teacher enquiry. However, it may well be at an important and necessary preliminary stage for such a group to transition from a group of like-minded individuals meeting to share ideas and practice to a more impactful PLC.

7. Discussion

The issues emerging from science teachers across the north-east of Scotland are very similar to those described by Tytler et al. (2011) in their paper describing the circumstances of teachers in rural northern Victoria in Australia, a drive of several hours from Melbourne, the main population centre of Victoria.

7.1 The tension between generic and subject-specific PL provision

Tytler et al. (2011, p876) identified the tension between generic and subject-specific PL as one of the main themes for secondary teachers in rural Australia. This is also the case for the teachers in this study. The teachers interviewed valued highly PL opportunities with their departmental colleagues and also the subject-specific PL from the likes of SSERC and IOP. Whilst having concerns about the operation of LA subject networks there was nevertheless a desire to see them become more effective through a greater focus on subject-based teaching and learning with good leadership and facilitation. This contrasted with the negative views displayed towards much generic and less context-specific PL and the PL often available during events such as whole-school in-service days. This is consistent with the findings of CUREE (2018, p20) where subject-specific PL was valued and sought after much more strongly by class teachers than school leaders.

The ability of a teacher to be effective very much depends on them having good SMK and PCK which corresponds to Foundation and Transformation knowledge as described by Rowland (2013). It is likely that experienced subject teachers will also have the good Connection and Contingency knowledge that is described by Rowland (2013) and which therefore makes having such colleagues a valuable asset for other colleagues to draw upon. Such teachers are likely to have a good knowledge of common alternative conceptions pupils may have and

strategies such as diagnostic and formative assessment, modelling, practical work, and questioning which can be used to move the learning of pupils forward. The research of McNicholl et al. (2013) demonstrates the significance of having such people accessible in a secondary school department and the importance of having a site, such as a departmental base, to facilitate the informal PL which is so valued by teachers. Physics involves practical work, with associated health and safety implications, therefore it is perhaps unsurprising that the sort of PL provided by organisations such as SSERC and IOP, which is firmly embedded in the context of the subject, is rated so highly by teachers. This is consistent with one of the criteria for PL programmes to achieve their full potential identified by Cordingley et al. (2015, p18) and CUREE (2018): that both subject knowledge and subject-specific pedagogy be considered together. Likewise PL which integrates knowledge and skills is a principle for effective PL identified by Timperley (2008, p11).

The identity of teachers in secondary schools as subject specialists has long historical and cultural roots. The organisation of secondary schools into departments or faculties is a universal phenomenon (Siskin 1994, p9) and these act as CoP (Wenger, 1998). Tytler et al. (2011, p878) describe '*discourse* communities' as a more useful term to describe the diverse connections made by teachers, a term which well describes the nature of the IOP-supported NLC. Secondary teachers experience a significant part of their ITE based on their subject specialism(s) and to become a secondary teacher in Scotland requires registration with the GTCS in one, or sometimes more than one, subject. This policy context, as Woolhouse and Cochrane (2015, p98) describe, as well as the '*discourse communities*' in which teachers find themselves, determines how teachers view themselves and therefore their PL also.

7.2 The overlapping but different agendas of the major stakeholders in teacher PL

Teachers and schools are subject to a mixture of not necessarily well aligned policy agendas: national; LA; school; department, and individual. Tytler et al. (2011, p877) describe the education system agenda with regard to PL as involving the dissemination of information about new policy directions and resources and the establishment of particular pedagogical, administrative and assessment practices. Similarly, Gilchrist (2018, p69) describes the traditional LA approach to PL for teachers in a rural LA in the south of Scotland as:

> "*a mish-mash of different activities that teachers opted in or out of, or which were imposed on us from outside by our local authority, and which usually changed on a yearly basis, or when we got a new Director of Education.*"

The teachers in this study made similar comments regarding the lack of clear vision or leadership for PL in their LA or school, the frequent lack, or poor communication, of any justification of why certain courses of action were taken, and in many cases a lack of consultation or involvement in decision making around PL which resulted in the experience of a top-down, transmissive approach to much LA provided PL. It lacks the active leadership identified as one of the principles for effective PL by Timperley (2008, p22).

Comments, such as the one made by a teacher referring to '*Big Brother*' are echoed by Gilchrist (2018, p89) when describing submitting his School Improvement Plan to his LA:

> "*it was submitted just before the start of our summer break, which meant no one could challenge anything in it until we returned in August, that is if anyone actually bothered to read these plans at all.*"

It was clear that teachers in all LAs wished to see better alignment of national, LA and school policy and a coherent approach to PL which would be consistent with the characteristics for effective PL described by Cordingley et al. (2015). Cordingley et al. (2015, p16) reported that positive PL environments, sufficient time, and a consistency with participants' wider context were all more important than whether teachers were conscripted or had volunteered to take part in PL. This was reflected in the comments of teachers who all held positive dispositions towards PL with what they considered worthwhile content (Timperley 2008, p10). Such PL is well focussed on teaching and learning, aimed at improving pupil outcomes (Timperley 2008, p8) and firmly embedded in their context. Resentment and negativity occurred when teachers felt conscripted and being told what to do with little explanation or apparent benefit to teaching and learning. This occurred frequently with regard to the use of school in-service days, similar to the findings of Bubb & Earley (2009, p8): these often being seen as a wasted opportunity.

As a Headteacher who wished to align the PL of his staff to their needs and to build their teacher agency through practitioner enquiry Gilchrist (2018, p46) describes the importance of Headteachers '*gate-keeping*' on behalf of their teachers to protect them from the '*initiativitis*' of others and the '*constant barrage of change and interference, most of which is imposed from above them in the hierarchies that still exist in most systems and many schools*'.

Scottish secondary teachers have more class contact hours than teachers in many other countries (OECD 2017, p381). On top of this the conflicting agendas imposed on teachers, along with significant ongoing curriculum and assessment changes, have increased workload and decreased the time teachers have for PL focussed on improving teaching and learning, particularly collaborative PL.

7.3 Remoteness and rurality

Remoteness from the Central Belt of Scotland appeared to be a more significant issue than rurality. There was a general willingness on the part of many teachers in the schools in the rural areas visited to meet for twilight sessions with teachers from nearby schools, issues such as child-care notwithstanding, provided the purpose was worthwhile. This was as reported by one network member in Hargreaves, Parsley, & Cox (2015, p317) "*you pay for what you value*", presumably with both time and money.

In Scotland most schools have more than one teacher in each of the three sciences within their science faculties. Fortunately the issues described by Tytler et al. (2011, p877) regarding the isolation of individual subject-specialists in very small schools, or teachers having to teach outside their specialism, does not occur widely. However, there were nevertheless concerns regarding the attraction of sufficient numbers of teachers, especially experienced teachers, in subjects such as physics to more remote areas and about the availability of suitable cover teachers. The recent trend in many LAs to replace the three PTs of biology, chemistry and physics with a single PT of science (HoF) was seen as a disincentive to attracting experienced members of staff in all three sciences to more remote schools where recruitment and retention can be an issue (Seith & Hepburn, 2017). This has the effect of reducing the likelihood of there being good KOs in all three subject disciplines for non-specialist teachers to draw upon, especially for the informal day-to-day PL valued so highly by teachers in this study.

On a positive note, the use of electronic communication such as subject-based email fora gave all science teachers the ability to discuss subject matters with colleagues from across the country and ready access to a variety of KOs, reducing the effects of distance compared to previous generations of teachers.

Recruitment and retention of teachers in subjects such as physics to remote areas is an ongoing issue. It has been shown that the provision of good quality subject-specific PL can reduce the numbers of teachers leaving the profession (Allen & Sims, 2017) but also in small schools working under difficult circumstances there is a tendency for more generic PL to be used rather than subject-specific PL (CUREE, 2018). There is a need to improve the awareness of LA and school leaders of the benefits subject-specific PL may bring to recruitment and retention of teachers in shortage subjects in remote area.

7.4 Collaboration and discourse communities

All teachers exhibited a desire to collaborate with others, both formally and informally, a principle for effective PL described by Timperley (2008, p19) and Cordingley et al. (2015, p28). It was recognised that it was appropriate for teachers to be members of several discourse communities as described by Tytler et al. (2011, p877): the department being one discourse community, particularly for PL with colleagues possessing other subject expertise when teachers were working outside their subject-specialism. The need to maximise the time subject-specialist teachers had to work collaboratively was clear and could be improved by spending more DM and in-service day time on discussing teaching and learning issues rather than administration (CUREE 2018, p11) and on better aligning national, LA, school, departmental, and individual teacher priorities. Despite usually identifying with their subject and department first, consistent with Siskin (1994) and Brooks (2016), teachers saw the benefits of the whole school, or the cluster of secondary school and its associated primary schools, working together as a second discourse community. They were positively disposed to the concept of cross-curricular PLC/TLC even if their experiences of the implementation of these had been less than positive in the past. There is clear potential for the further development of these discourse communities although this is challenging in secondary schools

because, as Tytler et al. (2011) acknowledge, teachers' identities are intricately bound up in their subject:

> "*Secondary teachers' identities are seen to be grounded in their knowledge and appreciation of the subject. Further their view of the subject is linked to their knowledge of what it means to teach it*." (p877)

A third level of discourse community of subject teachers across LAs, or appropriate geographical regions, has yet to be fully realised, despite the desire to see such effective NLC. A potential fourth discourse community is the wider community in which a school sits. This was not considered to any significant extent in this study. As a result many teachers are members of at least four fairly well defined overlapping discourse communities, see Figure 4.

Despite the desire to collaborate, for many teachers this was at a relatively superficial level, and for some there was clearly a feeling that '*contrived collegiality*' (Hargreaves & Dawe, 1990) was occurring within schools and especially at LA network meetings. Many saw LA network meetings as a good opportunity to share resources and compare progress between schools, and the informal opportunities to talk to colleagues more important than whatever was the intended formal business, much as Tytler et al. (2011, p874) describe. There was a desire for these to be more than the common practice of resource or news sharing, usually only by one representative from each school and only once per term, a scenario also described by CUREE (2018, p40), however, it was apparent that better leadership, facilitation, and a sustainable infrastructure are needed for this to occur (Timperley, 2008, p22; CUREE, 2018, p16).

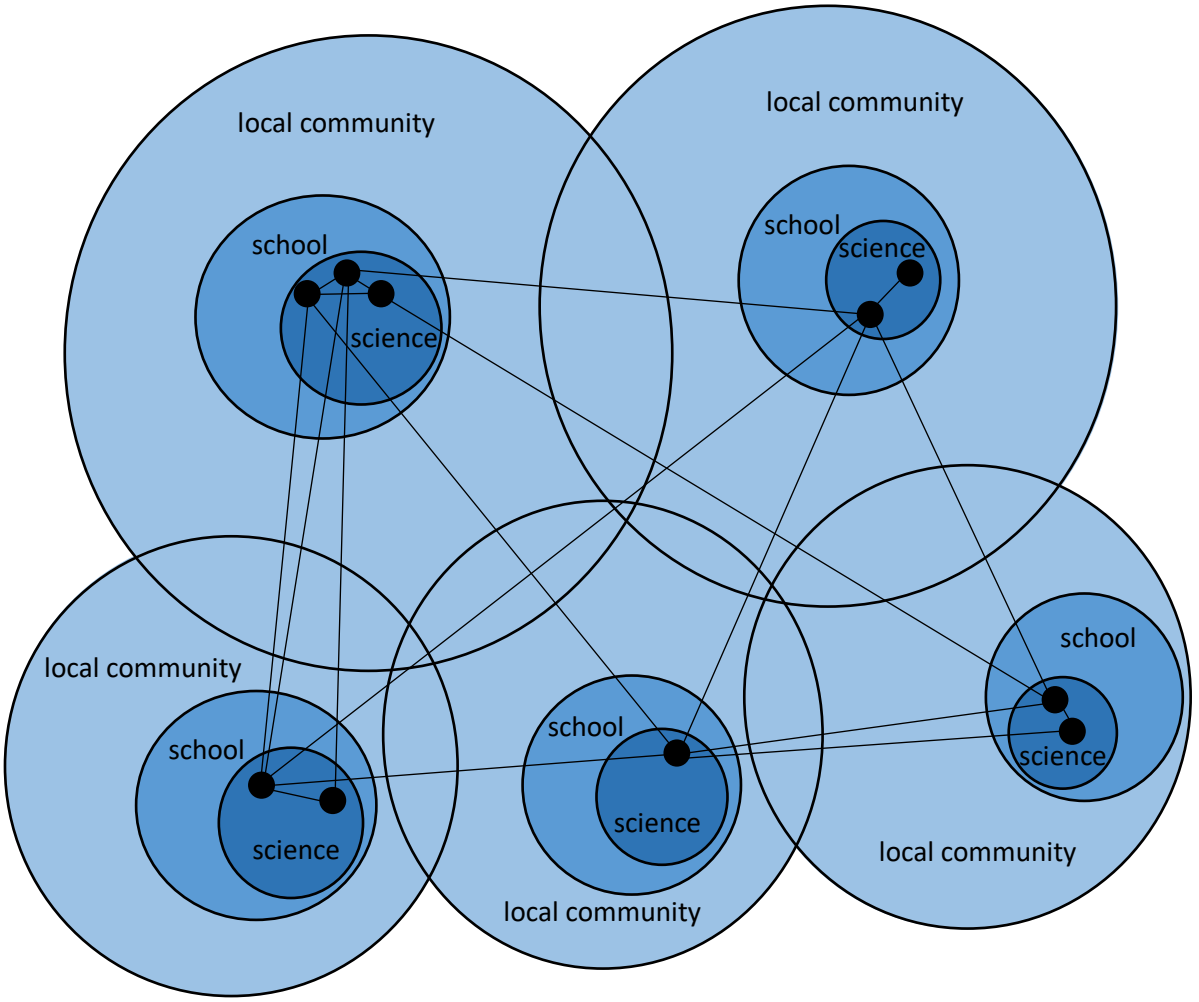


Figure 4: An exemplar of the four levels of discourse communities and how a NLC of ten physics teachers might sit within a geographical region containing five secondary schools each containing a science faculty.

7.5 Developing and supporting NLC

Having identified that discourse communities of the form of a NLC across a LA have not yet been fully realised, the intervention explored more deeply how this might be achieved with one group of teachers. The group was chosen, in part, because it had already passed beyond the '*starter*' phase as described by Bolam et al. (2005, p147) and benefited from already having a core group of PTs with an existing trusting, respectful, supportive ethos: an essential element for a NLC or PLC (Bolam et al., 2005, p138). This had developed over time through a

programme of LA subject network and IOP PL meetings for a group sharing a high degree of homophily and proximity (Coburn et al., 2010, p34) with a clear interest in improving teaching and learning in the context of their subject (CUREE, 2018). It was hoped this would more quickly help the NLC identify goals and a focus than a NLC starting from scratch (Hargreaves, Parsley, & Cox, 2015, p316), nevertheless this still proved to be a challenge.

A significant issue preventing progress in developing the NLC was the inconsistent attendance of teachers. The good working relationship between the PTs had developed when their attendance of the LA afternoon meetings was mandatory and there were signs of this diminishing under their less consistent attendance of the twilight events, similar to that reported by Prenger et al. (2017, p84). Although in theory this might have been off-set by the more inclusive nature of the meetings, this had not occurred as the others were less likely to attend, or may not have shared the same focus as the PTs due to not having a middle manager's interest in securing improved outcomes beyond their own classrooms (Harris & Jones, 2017, p214), or it just not being such an established habit-of-mind.

The NLC ought to be much more than a series of meetings. There ought to be ongoing collaborative working between meetings, and many have a desire to use additional strategies, such as peer-observation and lesson study, across and between schools. For this to occur it is essential that there is a coherence to the work of the NLC with a shared vision and purpose (Bolam et al., 2005, p134). This requires a more strategic approach and strong leadership and facilitation to see this through (Bolam et al., 2005, p143), and for activities to be sustained, continuous and embedded over time (Bubb & Earley, 2009, p9). For this to occur leadership capacity within the group needs building, so as to be less dependent on the IOP PNC, with wider acknowledgement and support from schools and the LA required to help optimise resource and structures, especially time (Bolam et al., 2005, p139; Hargreaves, Parsley, & Cox, 2015, p317). Few individual full-time teachers have the time, space or expertise to take on the

leadership of a subject NLC, despite many LAs expecting teachers to take on such a role with little support or training, very much against the advice reported in Hargreaves, Parsley, & Cox (2015, p318).

7.6 Access to KOs

All teachers valued collaboration with KOs from outside their immediate environment, a principle identified by Timperley (2008, p20), and sought greater contact with KOs, even if struggling to identify the best sources to meet their needs. The KOs were sought to input new ideas, facilitate PL and to challenge the status quo (Cordingley et al., 2007, p19). In a remote area, where access to KOs is limited, it is especially important to maximise the impact of those contributing in a sustainable manner unlike the situation described by Tytler et al. (2011, p875). In the intervention, in the absence of a LA subject officer to support the NLC, the IOP PNC played a key role in identifying KOs with subject-specific expertise both from within the NLC and beyond, as well as being a significant KO in terms of subject expertise, introducing new ideas and facilitating some of the communication within the NLC.

7.7 Enquiry – next steps

In only one of the focus group schools was there some evidence of a move to a more enquiry- and research-aware PLC building on a school-wide policy of subject-based TLCs. There was evidence of a desire amongst others in some schools to move in this direction but barriers including lack of time, conflicting demands, and lack of consistent leadership appeared to be preventing this from happening.

Enquiry may well be more appropriately organised at a school level, as described by Gilchrist (2018), rather than by an NLC. However, the NLC can support the enquiries of its members

through access to KOs, provide a conduit to share their findings to a larger audience with similar interests and concerns, and contribute through its members to any school-based PLC and enquiry activities (Jackson & Temperley, 2007, p52). Enquiry-based input to the NLC, along with an emphasis on evidence- and research-informed PL, may play an important part in raising the awareness of all teachers in the enquiry approaches required of Scottish teachers (GTCS, 2012b). There was some evidence of this beginning to occur in the NLC studied:

> "*Teacher enquiry is the next level and next step for me. We need to move on to it in the future. The style of the IOP twilights this year has moved to the 'how' we are teaching rather than the 'what', and that has made us more reflective*." T2

Whether by developing enquiry-based approaches or other forms of PL, if teachers are to develop improved teacher agency and adaptive expertise it is essential that sufficient resources, support and facilitation be provided throughout the system allowing a proper focus on teaching and learning that improves pupil outcomes. After all, that should be the raison-d'être of our education system.

8. Conclusions

Despite considerable efforts to simplify national guidance since the OECD review of Scottish education (Hargreaves, Timperley, et al., 2015), teachers in Scotland continue to receive conflicting policy messages. They are encouraged to exercise teacher leadership and agency but simultaneously accountability and performativity agendas act against this. Several decades of such agendas have deprofessionalised teachers (Biesta et al., 2015, p624) and constitute a barrier to teachers developing agency (Wallace & Priestley, 2017, p345). A symptom of this was the lack of confidence of some teachers in the NLC to organise activities

in their '*own time*' without acquiring some form of '*permission*' from their SLTs. Despite this there is a strong desire by teachers to undertake effective PL, to grow as professionals, and in the words of one interviewee "*to do the best for the kids*".

This study has shown that a NLC of physics teachers across a region can fulfil an important function. It can provide much needed subject-based PL (CUREE, 2018) which builds teachers' SMK and PCK and provides access to suitable KOs. However, developing and sustaining a collaborative NLC is complex: as Stoll et al. (2016, p362) conclude "*effective and sustainable change is hard*". For such a NLC to be effective it needs good leadership, support and facilitation from within its membership; from its immediate context of its schools and LA, and from KOs beyond, such as from an IOP PNC able to provide new ideas and challenge. This facilitation needs to support the members of the NLC to take ownership of the NLC and to identify realistic, specific goals. My own practice as an IOP PNC going forward, as well as being focussed on PL supporting the research-informed development of teachers' SMK and PCK, will place greater emphasis on supporting the growth of NLC leadership to ensure more self-sustaining NLCs. An important part of this is establishing a clear focus for the work of the NLC as well as a delivery programme. Developing the conditions for this would appear to take sustained effort over a significant timescale, longer than the nine months of this study.

Identifying a clear focus, and then moving on to impactful outcomes, might occur in a shorter timescale in a NLC where the main common feature of the teachers involved is a mutual interest in a particular relatively narrow topic or issue, rather than their main common feature being that they work for one LA as in this study. Even if the teachers involved are spread over a larger geographical area this might help the NLC develop more quickly along the lines described by Chen (2018) and this is worthy of further research. The recent growth of teacher-led PL events such as Pedagoo (Pedagoo, n.d.) and researchEd (researchED, n.d.) demonstrates there is a demand for such PL amongst some teachers and sufficient teacher agency

demonstrated by a small number to lead and organise these. Also worthy of further investigation is why, compared to the PTs, the unpromoted teachers in the study engaged less with the activities of the NLC, both attending fewer events and being less likely to respond to the questionnaires used in this study. Although there was not a clear divide between the years of experience of the unpromoted teachers and PTs, several of the unpromoted teachers in the sample were not likely to have reached Berliner's (2004) proficient or expert stages of teacher development and were therefore likely to benefit most from the PL. Whether schools are organised on a departmental or faculty basis may be a factor affecting teacher engagement and agency.

A subject-based NLC is only one discourse community of which a teacher should be a member. It is likely that a NLC working to complement school-based PLC practitioner enquiry approaches as described by Gilchrist (2018) will improve teaching and learning and the achievement and attainment of their pupils. In this scenario teachers are protected from competing demands and interference from above and allowed to focus, working in small groups with input from appropriate KOs, on evidence- and research-informed PL firmly embedded in their context. Genuine teacher agency can occur as a result. It appears that prioritising sufficient time to do this is a significant barrier and will require a change in mindset for many at various leadership levels as well as for many teachers themselves.

Time will tell whether the newly formed RICs will improve the collaborative working of Scottish teachers, help facilitate the PL they desire, and impact positively on pupil outcomes. LAs should be well placed to do this at the moment, but this study would indicate they are not functioning as well as they ought, despite being on a scale much more likely to enable groups of subject specialists to collaborate, both virtually and face-to-face, than the RICs. However, a RIC may be able to provide specialist support that the smaller LAs currently do not have the capacity to deliver. The Northern Alliance RIC which covers 58% of Scotland’s total land area

(Scottish Government 2017b, p24), would appear to run the risk of being another layer in a hierarchical structure on the wrong geographical scale to fulfil the needs of the teachers in this study. It would be disappointing if this structural change proved to be another example of what Fullan (1991) described:

> "*Nothing has promised so much and has been so frustratingly wasteful as the thousands of workshops and conferences that led to no significant change in practice when teachers returned to their classrooms*." (p315)

It is clear from both Cordingley et al. (2015) and CUREE (2018) that improvements will be best achieved through a focus on subject-specific PL at school and NLC levels. If this is implemented well perhaps the wish of one teacher interviewed will be met, and he will be "*trained to within an inch of my life*".

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[1] TeachMeets are non-commercial teacher sharing events organised 'by teachers, for teachers' consisting of short 2 or 7 minute presentations and Pedagoo events are similar to Teachmeets but with longer presentations or learning conversations typically of 30 or 40 minutes duration.

[2] The Scottish curriculum is divided into the Broad General Education (BGE) phase for ages 3-15 taught in nursery, primary and lower secondary schools and the Senior Phase for ages 15-18 where pupils are presented for Scottish Qualifications Authority (SQA) National Qualifications (NQ) courses.

[3] Travel times determined using AA Route planner, http://www.theaa.com/route-planner/index.jsp.

[4] Chartered Teacher status was introduced in Scotland in 2001 to reward teachers who wished to stay in the classroom rather than take up a management or leadership position. They received an increased salary which was dependent on them completing a Masters level education qualification. This arrangement was terminated in 2012.

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Appendix 1

Schools visited and teachers interviewed in the focus groups.

School code	LA code	Location	School roll	Teacher code	Post	Main subject
1	1	urban	590	11	Head of Faculty	Physics
				12	Teacher	Biology
				13	Teacher	Physics
2	2	small town	820	21	Teacher	Physics
				22	Teacher	Physics
				23	Teacher	Physics
				24	Head of Faculty	Chemistry
				25	Teacher	Biology
3	3	small town	750	31	Teacher	Physics
				32	Teacher	Chemistry
				33	Teacher	Biology
4	3	suburban	1040	41	Teacher	Physics
				42	Teacher	Physics
				43	Teacher	Physics
				44	Teacher	Biology
				45	Teacher	Chemistry
				46	Teacher	Physics
5	4	medium town	1000	51	Teacher	Physics
				52	Head of Department	Physics
				53	Teacher	Physics
				54	Teacher	Chemistry
				55	Teacher	Biology
				56	Head of Department	Biology
6	4	small town	540	61	Teacher	Physics
				62	Head of Department	Physics
				63	Head of Department	Biology

Appendix 2

Initial Focus Groups: Semi-structured interview schedule

Effective professional learning of teachers of physics in Scottish secondary schools

1. Teacher professional learning:
   - 1.1 In what ways are teachers professionals?
   - 1.2 How do you think teachers learn?
   - 1.3 Why do you think teachers' learning is important?
   - 1.4 Why is learning important in a professional context?
   - 1.5 What do you understand by 'professional learning'?
   - 1.6 Is 'professional learning' different from 'professional development'?

2. Forms of professional learning:
   - 2.1 What kinds of opportunities do you think teachers have to undertake professional learning?
   - 2.2 Which of these do you think are more/less valuable?
   - 2.3 Why?
   - 2.4 What kinds of opportunities do you think teachers value?
   - 2.5 Why?
   - 2.6 To what extent are teachers' professional needs and aspirations currently realised?

3. Schools:
   - 3.1 To what extent do you think that teachers' learning takes place in schools?
   - 3.2 To what extent do you feel teachers engage in collaborative learning?
   - 3.3 To what extent do you think that schools can be considered as professional learning communities?
   - 3.4 What do you think this entails?
   - 3.5 How might schools work together to enhance professional learning?

4. Support:
   - 4.1 To what extent are there roles for 'knowledgeable others' supporting the learning of individual teachers or groups of teachers?
   - 4.2 If so, why and how?
   - 4.3 If so, do you think you have access to appropriate 'knowledgeable others'?

5. The Future:
   - 5.1 How would you like to see teachers' professional learning develop in the future?
   - 5.2 In what ways do you feel you/your organisation may contribute to this?
   - 5.3 What barriers do you see preventing effective professional learning develop in the future?

6. Is there anything you feel we have not discussed which is important in this area?

Appendix 3

Study Timeline

Date	Activity
11 Sept – 4 Oct	Focus Groups
13 Nov	LA in-service day briefing of teachers about the study
15 – 24 Nov	Pre-intervention questionnaire period
27 Nov	NLC meeting 1: IRIS (KO1) and Best-Practice Sharing (All)
30 Jan	Meeting with LA Officer 1
30 Jan	NLC meeting 2: Diagnostic Questions (KO2) and Best-Practice Sharing (All)
(28 Feb	NLC meeting cancelled due to heavy snow)
21 Mar	Meeting with LA Officer 2
21 Mar	NLC meeting 3: Practical Electronics (KO3), Effective PL (KO2)
16 May	NLC meeting 4: Primary-Secondary Transition in context of Waves and Radiation (KO4, KO3, KO2)
29 May	NLC meeting 5: Practical Electronics (KO3, KO5, KO6)
19 – 20 Jun	Interviews
20 Jun	NLC meeting 6: Hinge Questions (KO3), Cognitive Load Theory (KO2) and Best-Practice Sharing (All)
13 – 27 Jun	Post-intervention questionnaire period

Appendix 4

Pre-intervention: Questionnaire

Sustaining effective collaborative inter-school Professional Learning Communities (PLC) of teachers of physics and the role of Knowledgeable Others (KO)

Collaborative inter-school working

Prior to this session four meetings per year were arranged by your Local Authority (LA) for Principal Teachers (PT) of Physics (or their representatives) from each school. Although part of the agendas of these meetings were set by the LA, these meetings gave those attending opportunities to discuss and collaborate on areas of their own choosing. These meetings also provided convenient dates for the local Institute of Physics Teacher Network Co-ordinator (PNC) to organise twilight professional learning (PL) sessions open to all teachers from the LA, and beyond, which were then followed by a more informal meeting over a meal for those who wished to continue.

1. Meetings of PTs/representatives from the different schools across the LA

1.1 How often did you attend meetings of PTs/representatives?

Frequently	Occasionally	Never

1.2 What added value did meetings of PTs/representatives from the different schools across the LA provide?

Space for answer

1.3 Do you consider these meetings helped to facilitate a Professional Learning Community (PLC) of physics teachers in the LA? Please justify your answer.

Space for answer

1.4 Did these meetings provide a forum for collaborative working and/or stimulate collaborative working between the meetings? Please justify your answer.

Space for answer

1.5 How much of the business of these meetings was focussed on improving the teaching and learning of pupils?

Space for answer

1.6 How well did these meetings support your physics PL needs?

Very well	Well	Some	Not at all

2. Twilight PL sessions

2.1 How well do these sessions support your physics PL needs?

Very well	Well	Some	Not at all

2.2 How well do you think these sessions meet the needs of different teachers, e.g. newly qualified teachers, experienced teachers, PTs etc.? If you do not know please leave blank.

Very well	Well	Some	Not at all

2.3 How well do these sessions help you share good practice or work collaboratively with other physics teachers?

Very well	Well	Some	Not at all

2.4 How well do these sessions provide input and support from appropriate Knowledgeable Others (KO)?

Very well	Well	Some	Not at all

2.5 How well do the informal discussions and networking both during the sessions and the meals that follow, support your PL?

Very well	Well	Some	Not at all

2.6 How might these sessions be improved to better meet your PL needs?

Space for answer

3. Future working

3.1 Is there a need for physics specific meetings in your LA? Please justify your answer.

Space for answer

3.2 If meetings are held, what do you consider to be the best means of setting the agenda so they best meet your needs?

Space for answer

3.3 If meetings are held, should decisions/actions be reported and if so by which method, and to whom?

Space for answer

3.4 Are there alternative ways of working which you think may be more efficient or effective at promoting your own PL and/or the teaching and learning of your pupils? If so, please give brief details.

Space for answer

3.5 How might the collaborative working of physics teachers across your LA be best facilitated?

Space for answer

3.6 Is there a need for increased collaborative enquiry focussed on improving the teaching and learning of your pupils?

Space for answer

4. Network support for teaching physics

4.1 Please identify teachers in your LA you have contacted directly (e.g. face-to-face, telephone, Skype or email) within the last year for advice on teaching and learning physics (please add rows as necessary).

	Frequency of contact		
Name of teacher	often	occasionally	once

4.2 Please identify teachers in your LA who have contacted you directly (e.g. face-to-face, telephone, Skype or email) within the last year for advice on teaching and learning physics.

	Frequency of contact		
Name of teacher	often	occasionally	once

4.3 Please identify others you have contacted directly (e.g. face-to-face, telephone, Skype or email) for advice on teaching and learning physics (please add rows as necessary).

	Frequency of contact		
Name of teacher	often	occasionally	once

4.4 Please identify online or social media sources you have used for advice on teaching and learning physics (please add rows as necessary).

	Frequency of contact		
Online or social media source	often	occasionally	once
Sputnik			
TalkPhysics			
Twitter			
Other (please specify)			

5. Any other comments

5.1 Any other issues or comments not already covered elsewhere.

Space for answer

Name of Participant _____ Date _____ Signature _____

Thank you.

Appendix 5

Post-intervention: Questionnaire

Sustaining effective collaborative inter-school Professional Learning Communities (PLC) of teachers of physics and the role of Knowledgeable Others (KO)

1. Which meetings did you attend? Put an **X** in the box of those which you attended.

	Date	Venue	Topics
☐	27 Nov 2018	School 1	IRIS (KO1), Sharing Session (All)
☐	30 Jan 2018	School 2	Diagnostic Questions (KO2), Sharing Session (All)
☐	21 Mar 2018	School 1	Practical Electronics (KO3), Effective PL (KO2)
☐	16 May 2018	School 2	Prim/Sec Transition, Waves and Radiation (KO4, KO3, KO2)
☐	29 May 2018	School 3	Practical Electronics (KO3, KO5, KO6)
☐	20 Jun 2018	School 1	Hinge Questions (KO3), Cognitive Load Theory (KO2), Sharing Session (All)

2. How well were your professional learning (PL) needs met by these meetings?

Very well	Well	Some	Not at all
☐	☐	☐	☐

3. Was there a particularly good session? If so, please explain why.

Space for answer

4. How well do you think the PL needs of different teachers, e.g. NQT, experienced, PT, etc, were met by the meetings?

Very well	Well	Some	Not at all
☐	☐	☐	☐

5. How well did the meetings allow the sharing of good practice?

Very well	Well	Some	Not at all
☐	☐	☐	☐

6. Do you think enough time at meetings was focussed on teaching and learning?

Yes	No
☐	☐

7. At the start of 2017-2018 did you feel remote from, or have difficultly accessing, any of the following?

	Yes	No
Advice from, or discussion with, other physics teachers		
Advice or input from KOs		
Effective professional learning opportunities		

8. How well did the meetings in 2017-2018 improve any feelings of remoteness or difficulty of access?

	Very well	Well	Some	Not at all
Advice from, or discussion with, other physics teachers				
Advice or input from KOs				
Effective professional learning opportunities				

9. How well did the meetings promote collaborative working?

Very well	Well	Some	Not at all

10. How well did the meetings promote collaborative working between the meetings?

Very well	Well	Some	Not at all

11. How well did the meetings promote teacher enquiry into professional practice?

Very well	Well	Some	Not at all

12. Were the inputs from KOs appropriate?

Always	Mostly	Some	Not at all

13. How well did the meetings allow access to expertise and KOs from outwith the local area?

Very well	Well	Some	Not at all

14. Were the meetings a valuable replacement for the previous meetings of PTs/representatives?

Yes	No

15. Were the notice of meetings, agendas, notes and outputs of the meetings communicated appropriately?

Very well	Well	Adequate	Inadequate
☐	☐	☐	☐

16. Did the meetings occur with an appropriate frequency?

Too often	Ok	Not often enough
☐	☐	☐

17. Were the meetings of an appropriate length?

Too long	Ok	Not long enough
☐	☐	☐

18. Were there sufficient informal networking opportunities during or after meetings?

Too much	Ok	Not enough
☐	☐	☐

19. Were the meeting venues appropriate?

Yes	Sometimes	No
☐	☐	☐

20. Would you wish to keep on meeting, with IOP input?

Yes	No
☐	☐

21. Would you wish to keep on meeting, without IOP input?

Yes	No
☐	☐

22. Would you be prepared to take a role in organising future events?

Yes	No
☐	☐

23. How could the meetings be improved? If yes, please give details.

Space for answer

24. Are there specific PL needs you would wish to have addressed in the future? If yes, please give details.

Space for answer

25. Do you have any suggestions for how the IOP could continue to support your needs? If yes, please give details.

Space for answer

26. Please identify teachers in your LA you have contacted directly (e.g. face-to-face, telephone, Skype or email) within the last year for advice on teaching and learning physics (please add rows as necessary).

	Frequency of contact		
Name of teacher	often	occasionally	once

27. Please identify teachers in your LA who have contacted you directly (e.g. face-to-face, telephone, Skype or email) within the last year for advice on teaching and learning physics.

	Frequency of contact		
Name of teacher	often	occasionally	once

28. Please identify others you have contacted directly (e.g. face-to-face, telephone, Skype or email) for advice on teaching and learning physics (please add rows as necessary).

	Frequency of contact		
Name of teacher	often	occasionally	once

29. Please identify online or social media sources you have used for advice on teaching and learning physics (please add rows as necessary).

	Frequency of contact		
Online or social media source	often	occasionally	once
Sputnik			
TalkPhysics			
Twitter			
Other (please specify)			

30. Do you have any other suggestions or comments? If yes, please give details.

Space for answer

Name of Participant _____ Date _____ Signature _____

Thank you.

Appendix 6

Post-intervention: Semi-structured Interview Schedule

Sustaining effective collaborative inter-school Professional Learning Communities (PLC) of teachers of physics and the role of Knowledgeable Others (KO)

1. How well did the meetings provide a forum for collaborative working and/or stimulate collaborative working between the meetings?

2. Do you consider these meetings helped to facilitate a Professional Learning Community (PLC) of physics teachers across the LA?

3. Literature shows that teacher enquiry focussed on supporting pupil learning has a significant impact on raising attainment. How well do you consider these meeting helped encourage such teacher enquiry?

4. Whether involving teacher enquiry or not, how well was a focus on pupil learning encouraged during the meetings?

5. Literature shows that teacher networks and PLC benefit from the input of KOs. Do you think there was appropriate input from KOs which provided:
   (a) advice and support;
   (b) challenge to the status quo?

6. Compared to the previous LA organised meetings for PTs held during a working afternoon please comment on the use of twilight meetings. You may wish to consider factors such as:
   (a) twilights being in a teacher's 'own time';
   (b) twilights being open to all teachers and not just one teacher per school;
   (c) control over agendas;
   (d) whether the functions of the PT meetings have been fulfilled by other means.

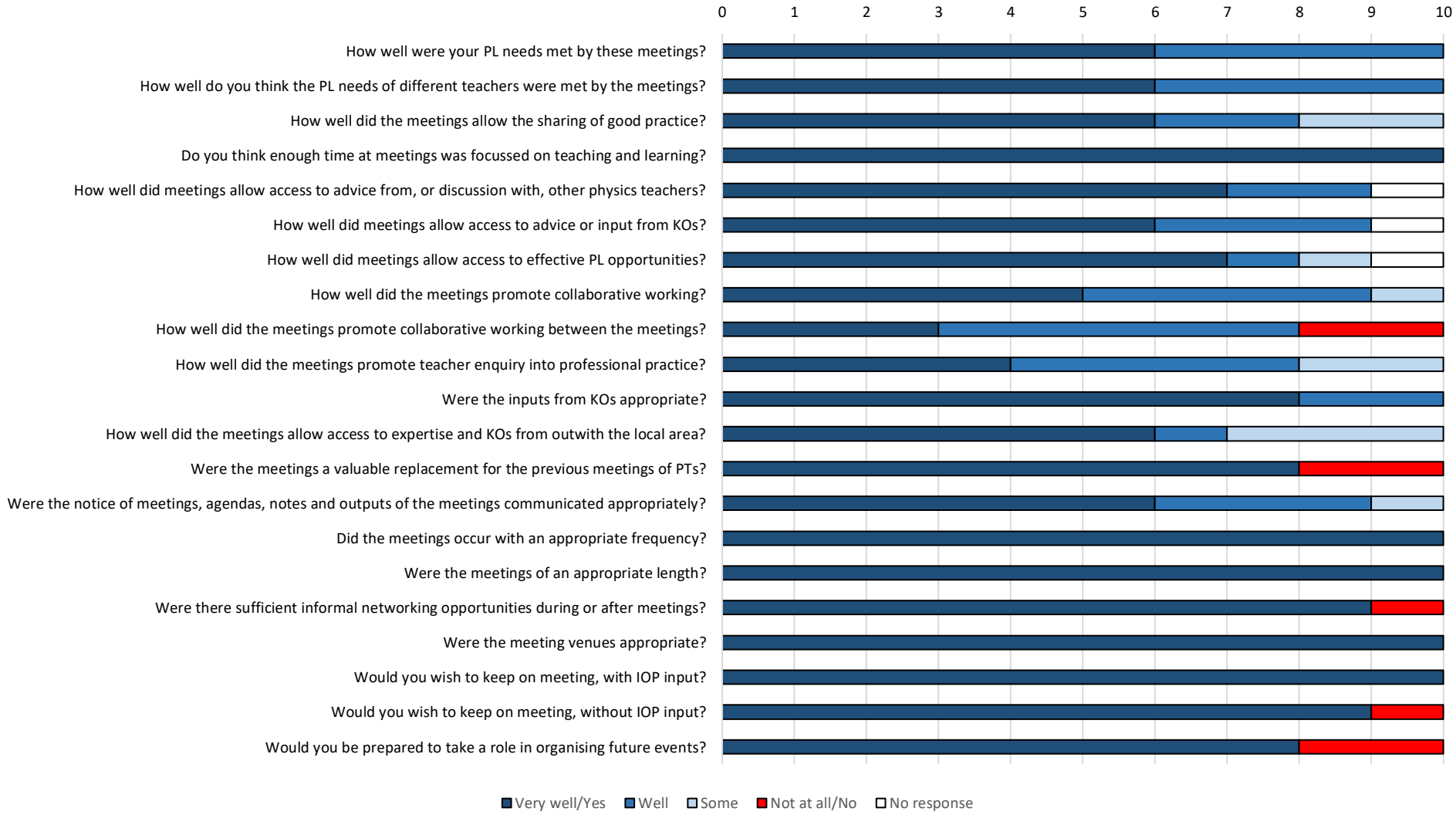
7. Please comment on the leadership and facilitation needed to ensure effective twilight meetings.

8. Please comment on the support for the PL of physics teachers across the LA and how you think this can be best met going forward?

9. Is there anything you feel we have not discussed which is important in this area?

Appendix 7

Frequency distributions of responses to the post-intervention rating-scale questions



Appendix 8

List of Acronyms

APT	Assistant Principal Teacher
BGE	Broad General Education (for ages 3-15 in Scotland)
CLPL	Career-Long Professional Learning
CoP	Community of Practice
CPD	Continuing Professional Development
CT	Chartered Teacher
DM	Departmental Meeting
FM	Faculty Meeting
GTCS	General Teaching Council for Scotland
HoF	Head of Faculty
IOP	Institute of Physics
ITE	Initial Teacher Education
KO	Knowledgeable Other
LA	Local Authority
MOOC	Massive Open Online Course
NLC	Networked Learning Community
NQ	National Qualifications (SQA courses in Senior Phase – ages 15-18 in Scotland)
NQT	Newly Qualified Teacher
OECD	Organisation for Economic Co-operation and Development
PCK	Pedagogical Content Knowledge
PD	Professional Development
PG	Professional Growth
PL	Professional Learning
PLC	Professional Learning Community
PLD	Professional Learning and Development
PNC	Physics Teacher Network Co-ordinator
PT	Principal Teacher (usually Head of Department or Faculty in a secondary school)
QIO	Quality Improvement Officer
RIC	Regional Improvement Collaborative
RQ	Research Question
SCEL	Scottish College for Educational Leadership
SLT	Senior Leadership Team (in a school, sometime SMT – Senior Management Team)
SMK	Subject Matter Knowledge
SQA	Scottish Qualifications Authority
SSERC	Scottish Schools Education Research Centre
T1-T10	Teachers quoted in text
TLC	Teacher Learning Community