PROFESSIONAL REFLECTIONS

International Perspectives on Science Teachers' Continuing Professional Development

The National Science Learning Centre and the University of York Science Education Group

June 2010

In February 2010, the national network of Science Learning Centres and University of York Science Education Group (UYSEG) jointly hosted a three-day seminar at the National Science Learning Centre at the University of York. The intention was to bring together experts in science education to share experiences of good practice in continuing professional development (CPD), in particular CPD that is considered to have had a significant positive impact on practice.

Professional Reflections presents a summary of the presentations and discussion from the event to stimulate further thinking about the future direction of CPD in science education.

NATIONAL NETWORK OF SCIENCE LEARNING CENTRES

Science Learning Centres are a national network for professional development in science teaching. Their aim is to improve science teaching and to inspire students in schools and colleges by providing them with a more exciting, intellectually stimulating and relevant science education, enabling them to gain the knowledge and the understanding they need – both as the citizens and as the scientists of the future. The network comprises nine government-funded Science Learning Centres for the English regions, led by an independently funded National Science Learning Centre for the whole of the UK.

Science Learning Centres are jointly funded by the Department for Education in England and the UK's largest charity, the Wellcome Trust, and aim to provide CPD of the highest quality for everyone involved in science education, at all levels.

In 2008-09 over 19,600 training days of high quality programmes took place across 11 major themes, with participants from 73% of secondary schools and 17% of primary schools in England.

UNIVERSITY OF YORK SCIENCE EDUCATION GROUP (UYSEG)

The University of York Science Education Group is a leading centre for research and development in school science education. It is an informal grouping of science education specialists from the Centre for Innovation and Research in Science Education (CIRSE) in the Department of Educational Studies and the Chemical Industry Education Centre (CIEC), part of the Department of Chemistry.

Acknowledgements:
The conference was organised by Professor Mary Ratcliffe, National Science Learning Centre, and Professor Robin Millar, University of York Science Education Group. It continues a series of international seminars in science education jointly organised by science educators at York and the Leibniz Institute for Science and Mathematics Education (IPN), Kiel, Germany. We are grateful to all attendees for their active participation in presenting papers, acting as discussants, chairing sessions and in their contribution to wider discussion.

Thanks go to:
Rosalyn Sands for administration
Rosalyn Sands, Irina Kudenko and Peter Finegold for summarising sessions
The Wellcome Trust for supporting the seminar.

Report author: Peter Finegold, Isinglass Consultancy Ltd
Design: Jag Matharu, Thin Air Productions Ltd
Photography: Andrea Mapplebeck and Richard Needham
Published by the National Science Learning Centre

June 2010

EXECUTIVE SUMMARY

In February 2010, the national network of Science Learning Centres and University of York Science Education Group jointly hosted a 3-day seminar at the National Science Learning Centre at the University of York. The purpose of the seminar was to bring together experts in science education to share research into good practice in continuing professional development (CPD) in science education.

Some 45 CPD experts came together to explore the latest research and practice perspectives from around the world, focusing on what is known about effective CPD, how best to understand its impact, and how to develop capacity and leadership. These experts comprised leading international researchers and professional tutors from each of the ten UK Science Learning Centres.

The seminar addressed three key questions, drawing on examples of leading-edge research on effective CPD in science education.

1 What do we know about effective CPD in science education?

To answer this question, sets of examples of research were used to reflect on three interrelated themes of professional development:

Content – development of pedagogical content knowledge at the heart of effective science teaching;

Methods of engagement – involvement of teachers in curriculum projects;

How better to understand the process of change through making use of modern technologies such as digital video.

2 What do we know about methods of, and approaches to, understanding the impact of CPD?

Seminar participants explored the outcomes of evaluations which used different frameworks and methods to understand the impact of CPD on professional practice.

3 How can we build capacity and leadership in development of effective CPD?

This question was an underlying theme throughout the seminar, with recommendations and principles being brought together in the final plenary session.

In interactive sessions, participants examined innovative approaches to science CPD and methods used to assess its impact. Outcomes from discussions helped determine recommendations for development of CPD, engagement with stakeholders and other emerging themes, including an agenda for future research.

Participants addressed these themes through consideration of specific areas of research.

1 What do we know about effective CPD in science education?

Content: 'Pedagogical content knowledge' (PCK) has been described as the "unique combined skills of the subject teacher in teaching particular science concepts to particular pupils". Research projects have been successful in understanding and describing teachers' PCK. There is great potential for CPD to help teachers significantly develop their PCK, and make explicit their otherwise tacit knowledge of teaching and learning specific science topics and ideas.

Methods of engagement: Some teachers seek professional development for reasons of career progression, acquisition of specific skills and personal growth. However, the drive to change practice will more often come from curriculum or assessment initiatives. Research has shown how engagement in curriculum projects, for example, can lead to the development of reflective CPD communities, participating across and within schools, and between teachers, researchers and CPD providers.

Techniques: A new generation of video software tools has presented teachers and professional development experts with new opportunities for analysis of practice and reflection on professional skills and attitudes. Judicious use of the technology presents new ways in which teachers can work collaboratively to develop their thinking and expertise. Easy-to-use video technology and online social networking offer an array of new opportunities for CPD in aiding reflective practice.

Some important, additional themes developed from consideration of the research examples related to what we know about effective CPD:

- Effective and reflective experiences of CPD affect a teacher's professional self-image and the likelihood that they will remain open to experimentation in practice throughout their career.
- Much recent research into effective professional development in science education acknowledges the interaction between CPD and the personal and social development that is essential for change to occur. This interplay between knowledge, experience and beliefs can pave the way for continuous refinement as new ideas are put into practice.

2 What do we know about methods of, and approaches to, understanding the impact of CPD?

- More effective and wider adoption of CPD requires the provision of high quality data on its potential impact on young people. The complexity of the classroom makes it difficult to infer that any observed change in students' attainment is principally due to change in a teacher's knowledge or skills resulting from 'in-service' training since so many factors influence learning outcomes. This poses a major challenge for research that aims to evaluate the impact of CPD on students' learning.
- The Science Learning Centres are gathering evidence to explore changes in teachers' and schools' practice as a result of CPD and potential impacts on learning. Multiple methods, such as the use of an 'impact toolkit' on a large scale combined with case studies of teachers' and students' learning, can give a rich picture of the impact of national professional development.
- Artefacts, such as portfolios of teachers' work or logbooks, can be used as a reflective record of quite diverse evidence of impact, demonstrating development in practice over time. The approach has been shown to work for national initiatives with large samples of teachers logging an extensive array of material as evidence of change in their practice. Equally, structured analysis by groups of teachers of portfolios of student-generated material has been shown to contribute to helping teachers, especially in their early years in the profession, to generate and test hypotheses about how they teach and to encourage them to be more creative in their approach.

Outcomes of the seminar

Seminar participants identified some ongoing issues in science teachers' professional development. For example, how can the expectation that science teachers will engage in CPD become embedded in schools' and teachers' thinking and planning?

Through the discussions, several important principles emerged, based on the evidence reviewed. There was broad consensus among seminar participants that these principles provide a foundation for developing further the work of the science CPD community:

- Collaboration between teachers, professional development leaders and researchers has potential to be highly productive in supporting professional development which has impact on practice.
- Professional development experts occupy a niche as mediators of new ideas and emerging research. Positioned between academic research and classroom delivery, they have a role in guiding teachers at all stages of their careers, employing research findings to promote autonomous reflective practice and brokering the relationship between all the participants in the process.
- CPD works best when it takes place over time, punctuated with opportunities to reflect on, and apply, the ideas under consideration in a school setting.
- Sustained reflective professional practice is more likely to arise if there exists a collegial approach to professional development.
- Fruitful and productive reflection on practice is often stimulated by the perspectives that researchers familiar with the wide science education literature, and others working outside the classroom, can bring to the CPD context.
- It is important that CPD enables teachers to learn from their own and others' practice.
- A culture of reflective professional practice should be instilled pre-service, and continue throughout a teacher's career.
- There is a need for a diverse repertoire of approaches to CPD, including those that start small but can be rolled out on a larger scale.
- Engaging teachers in curriculum development is often an effective means of professional development.
- Modern technology, when used intelligently, can provide access to examples of practice in a manner that stimulates individual and collaborative reflection. Its potential should be more thoroughly explored.

> "To achieve sustained change in practice, professional development involves practitioners, researchers and CPD providers working collaboratively to impact on pupils' learning, using evidence-based consensus models in a scalable way."

A discussion group's summary of emerging messages from the seminar

Engagement with stakeholders

Participants acknowledged the complexity of the environment in which CPD takes place. A significant amount of work is required to ensure that professional development meets the needs of the science education community. To meet these challenges it may be necessary to:

- **Clarify the message**: Both the research and CPD communities need to communicate clearly with policymakers, making use of robust evidence of outcomes of CPD to inform policy developments related to high quality professional development.
- **Build alliances**: Go beyond developing networks to build strategic relationships, nationally and internationally.
- **Agree priorities**: For example, identify some key pedagogical principles that should be placed at the centre of teacher education.
- **Refine the evidence base**: Attempt to develop a unifying model for evaluating impact.

INTRODUCTION

International research and development seminar on continuing professional development for science teachers

The seminar brought together experts in science education to share experiences of good practice in continuing professional development, in particular CPD that is considered to have had a significant positive impact on practice.

Participants comprised leading researchers and practitioners in science education professional development from around the world. Over three days at the National Science Learning Centre in York they presented a range of perspectives and discussed how prevailing ideas emerging from academic research can both illuminate and be applied to practice.

The seminar programme was designed around three key high-level questions:

- **What do we know about effective CPD in science education?**
- **What do we know about methods of, and approaches to, understanding the impact of CPD?**
- **How can we build capacity and leadership in development of effective CPD, particularly in relation to early career professionals and career progression?**

These questions determined the seminar aims:

1. **To review evidence from practice and research of what works best in science CPD.**
2. **To identify where further research and further development could be usefully carried out.**
3. **To inform the thinking of participants, in particular staff in the Science Learning Centres network, about CPD provision and course design, and develop the capacity of the network to engage with research and researchers working on CPD.**

Seminar participants critically considered a range of important research projects that examine aspects of impact of CPD for science teachers and attempted to draw out the practical implications that these research findings raise for CPD practice. They identified themes, approaches, and opportunities for future research and development in the field that would contribute to international understanding of this area of science education.

The involvement of Science Learning Centre staff allowed them to reflect on and share their practice in an international research-focused context.

It is hoped that similar future events will help contribute to building capacity in research and development of CPD in the UK and support the position of the national network of Science Learning Centres as leaders in the field of professional development in science education.

SECTION 1

Developing Professionals

The process of educating young people is complex and requires a sound knowledge base, a comprehension of underlying ideas, the ability to communicate effectively and sensitivity to the perspective of the learner. The social and political contexts in which learning takes place and the personal values and attitudes of participants add to the complexity. Expertise in teaching, as with many other human activities, comes as a result of a lifelong aspiration to do it better, leading to constantly evolving reflective practice.

The first seminar session set out to address some of this complexity by exploring what is known about effective CPD in science education and how some of these ideas are put into practice. Specifically, participants considered international approaches to professional development programmes that:

- enhance pedagogical content knowledge – a mix of subject knowledge and teaching approaches that forms a teacher's '*own special form of professional understanding*'[1]
- use new technologies to promote reflective practice at the core of professional development
- employ project-based approaches to foster sustained change in practice

The ultimate aim of professional development is to produce knowledgeable, confident and competent teachers who have at their disposal a repertoire of approaches they can deploy, based on a sound understanding of what is known to work and professional intuition that has been honed over time.

If professional learning is the process that leads to changes in specific knowledge, skills, attitudes and beliefs, then true professional development is said to have taken place when the individual teacher has exhibited demonstrable growth, notably having:

"undergone broader changes that may take place over a longer period of time resulting in qualitative shifts in aspects of teachers' professionalism"[2]

The challenge for CPD providers is how to shape their programmes and approach so that more teachers will experience the step-change in professionalism that has been shown to result in better practice and more effective learning.

Shirley Simon of the Institute of Education, London, described how much recent work in this area has been built on Bell and Gilbert's model for achieving teacher development.[3] The model acknowledges the interaction between professional development and the personal and social development that are considered essential for change to occur.

Simon characterised the interplay between knowledge, experience and beliefs on the one hand and professional actions on the other, as:

"a combination of knowing in your head and learning in your actions"

...leading to continuous refinement as new ideas are put into practice and reflected upon.

Reflective practice was a recurring theme throughout the seminar. However, in his opening presentation, Justin Dillon of King's College London queried use of the term: although everyone espouses the concept, do we really know what we mean by it, where does it happen and how can teachers get better at it?

"I'd like to go to sleep right now and wake up as a teacher"

(Female student teacher, overheard in conversation)

Dillon proposed that a teacher's professional self-image is determined by reflective engagement – with those who maintain experimentation and diversification in their practice (what Huberman refers to as 'tinkering'[4]) leaving the profession at the end of their careers fulfilled and in a serene state of mind[5]. It is this very tinkering that leads to the transfer of knowledge between teachers and is, he maintains, absent from most top-down initiatives that set out to disseminate good practice. Instead, there tends to be dissemination of information about good practice, with inadequate recognition that:

"tinkering – and space and support for it – is essential for the conversion into new professional knowledge to occur."

Exemplifying the challenge: The 'Talking to Learn, Learning to Talk' project

Talking to Learn, Learning to Talk in Science (TTL) is a current research programme in which students follow a curriculum where they and their teachers address learning tasks together, through debating and questioning scientific knowledge, claims, evidence and issues. TTL makes use of discussion amongst students and argumentation in both scientific and social contexts to develop critical thinking skills and reasoning.[6] In many ways the project represents a wider shift in the aspiration of many education systems that see the development of an effective independent approach to study at the heart of lifelong learning.

Shirley Simon described the difficulties that teachers face in adopting new approaches that conflict with existing beliefs about teaching and what it means to learn science. Simon states that science teachers traditionally see their role as mediators between their students and the body of scientific knowledge:

"We have found that teachers conceptualise science teaching primarily as providing access to established knowledge through teacher-led classroom processes."

If new ways of learning are to become embedded, it is not enough to introduce a new teaching and learning approach through an alternative curriculum. The environment in which teachers operate has to be nurtured to promote change in professional self-perception:

"To value discussion-based activities such as those involving argumentation requires a shift in how science teaching is viewed. Implementing strategies for discussion and valuing student contributions requires a radical shift for some teachers."

The broad questions being asked by Simon and her research colleagues echo those both explicit and implied in many of the seminar presentations:

1. Does a cycle of collaborative reflective professional learning enable science teachers to change their pedagogic practice to one that is more dialogic?
2. What is the value of school department focused collegial meetings for sharing and reflecting on practice?

The emerging evidence, based on qualitative analyses from various sources, indicates identifiable change in professional reflection in some cases. A teacher from a school participating in the research study demonstrated a shift from simply transmitting knowledge to a more dialogic approach, illustrated in these two quotes captured at the start of the research and then the same individual a year later:

JUNE 2008

"If they are not listening, they are not going to hear, so they are not going to recall the information or even hear the information."

JUNE 2009

"…it's helped them to use the correct language and the correct context and argue their point with their evidence."

If we accept the rationale for this type of approach to learning, then the professional development community has to play its role in supporting teachers to undergo the personal challenges in their learning that will then lead to developments in practice.

The unique combined skills of the subject teacher: Pedagogical content knowledge

Science as an activity comprises an unimaginably vast body of knowledge organised around a set of underpinning concepts, principles and methodologies that are elaborate and complex. The science teacher has the role of distilling this complexity into models and metaphors that are meaningful to the student that build on pre-existing understanding and contribute to future development of ideas.

This challenging role draws heavily on what has come to be known as *pedagogical content knowledge(PCK)*[7], and which comprises two main elements:

1. knowledge of representations of the subject matter
2. knowledge of conceptions and learning difficulties linked to that subject matter

Lee Shulman, who first proposed PCK as one of the categories of teachers' professional knowledge, suggested that PCK (which comprises these "*most powerful analogies, illustrations, examples, explanations and demonstrations*") is "*the category most likely to distinguish the understanding of the content specialist from that of the pedagogue*". In so doing, Shulman identified the unique role of the teacher.

The seminar discussed two research-informed approaches for developing PCK amongst science teachers. The first from Jan van Driel of the University of Leiden described a model for developing PCK that attempts to explore its relationship with other key factors. These include teachers' disposition towards professional experimentation, levels of collegial cooperation and exchange, and the role of external input, including research outputs.

Van Driel argues that PCK is a complicated process, which does not proceed in a simple linear manner. He has adapted a model (Fig.1) first developed by Clarke and Hollingsworth to demonstrate how PCK is more likely to develop through a combination of elements comprising access to appropriate external stimuli, experimentation in the classroom and interactions with colleagues. Within the model, he proposed that teachers' existing professional knowledge also helps in the development of new PCK. In applying these ideas to the design and delivery of CPD courses or programmes, he suggested that they should include external input and experimentation in practice, as well as collegial interactions, and that such a comprehensive approach is potentially more powerful than approaches that are restricted to some of its elements.

Amanda Berry, Monash University, is engaged in work to capture and portray PCK in a way that helps teachers recognise and develop their own in relation to particular science content. She and her colleague, John Loughran, advocate promoting PCK in professional development programmes, which they suggest also:

"better values teachers' professional knowledge of practice, creating a vision for their ongoing professional learning."

To date, the idea of PCK has been used mainly by researchers rather than being seen by CPD providers as central to the task of helping teachers to improve practice. Berry suggested that wider awareness of their PCK by teachers in practice could:

"make the tacit explicit and lead to a purposeful refining of [one's] expertise."

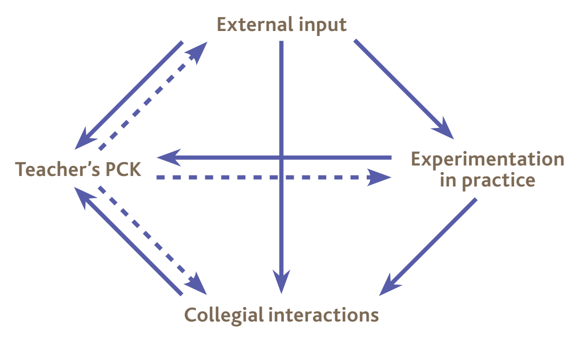


Fig. 1. Model for the development of teachers' PCK.

This is necessary, she maintains, since teachers are not used to articulating what they know or what they do. But Berry believes that teachers are "pedagogical decision makers" a view that she feels has:

"increasingly come to be recognised as a vital centrepiece to new understandings of professional development."

Berry and Loughran have been engaged in work to explore how PCK might be portrayed in ways that are meaningful and applicable for teachers' practice.[8,9,10] Their research is based on interviews with experienced high school science teachers in Australia about how and why they taught particular science content in a specific way. Over time they arrived at two headings for these representations: (i) Content Representations (CoRes) and (ii) Pedagogical and Professional-experience Repertoires (PaP-eRs).

CoRes represent the PCK of expert teachers around a specific science topic (such as chemical reactions) and make explicit what would otherwise be tacit. PaP-eRs provide a narrative account that illustrate PCK in action – typically, a discussion between two teachers on how to approach a topic, an annotated curriculum document or feedback on the learning experience by a student.

The implications for CPD delivery in considering the two approaches to PCK generated observations and questions, including:

- That both models emphasise the importance of collegial engagement.
- Their potential to raise teachers' professionalism, enhance their status and raise their awareness that they 'have important knowledge'.
- Whether there should be a range of well-grounded frameworks, like these, available.
- How will making explicit the tacit professional expertise map onto the reality of teachers' practice and experience?
- What is the potential for these and other frameworks to develop a collaborative culture of critical and skillful reflection – promoting a 'learning mindset' amongst teachers?
- What needs to be in place in schools and elsewhere for these approaches to succeed?

Seminar participants felt that CPD providers might act as mediators between researchers, the frameworks themselves and the teachers, including the development of a common language. CPD providers would also be pivotal in encouraging teachers to take necessary ownership of their professional learning whilst being able to respond to teachers' needs.

Effective professional development arising out of project-based learning approaches

Though career progression, acquisition of specific skills and personal growth are reasons why teachers seek professional development opportunities, the drive to change practice will more often come from activity having immediate implications for the classroom, such as curriculum development or new assessment models.

Two international approaches were presented to illustrate how innovation in students' learning can be the driving force behind reflective professional practice. These models show how school-focused initiatives, such as context-based learning and the development of higher order learning strategies, can contribute to teachers' reflective practice, effectively driving professional development.

Context-based learning programmes have typically been developed to counter declining interests in science. In some cases such programmes illustrate the connections between basic concepts and real-life situations, while in others they are employed to promote wider scientific literacy. Ilka Parchmann of the Leibniz Institute for Science and Mathematics Education in Kiel outlined the underlying rationale for the work that she has carried out with Markus Luecken, showing how embedding scientific concepts in authentic contexts increases interest and motivation amongst students and leads to better learning.[11] Their research is based on three German context-based approaches[12] which generated their own teacher training programmes focusing on teacher cooperation as one important condition for successful implementation.[13,14,15,16,17]

Teachers worked alongside subject-based university researchers for three years or more in 'learning communities' to develop teaching units and materials, which were then used in teacher training courses.[18,19,20] By being provided with only the frameworks and exemplary materials for the learning communities, the teams of teachers and researchers developed the new units for each of the context-based approaches in 'symbiotic communities' – the teachers contributing practical know-how, with the researchers presenting state-of-the-art theory and empirical evidence. Parchmann and Luecken describe how the outcome confronted teachers with new ways of viewing their teaching:

"they had to deal with empirical results and discuss their impact on their own teaching traditions, which are not usually an important background for the teachers' preparations in Germany." [21]

The researchers gained insight into thinking approaches, belief systems, constraints and processes linked with real teaching. In terms of attitudinal change, the research team identified that, for example, within the *Biologie im Kontext* (Biology in Context) scheme, there emerged clear intentions to implement the new approach at the end of the project.

Zahava Scherz of the Weizmann Institute in Israel presented another example of a CPD project that has led to change in teachers' practice, based around the Learning Skills for Science programme (LSS). The programme was designed in Israel in 1996 and has been adapted for use in the UK – funded as part of the Science Enhancement Programme by the Gatsby Foundation.

Learning Skills for Science was designed to incorporate the acquisition of skills into the learning of school science content, including:

- information retrieval
- scientific reading
- scientific writing
- listening and observing
- information representation
- knowledge presentation

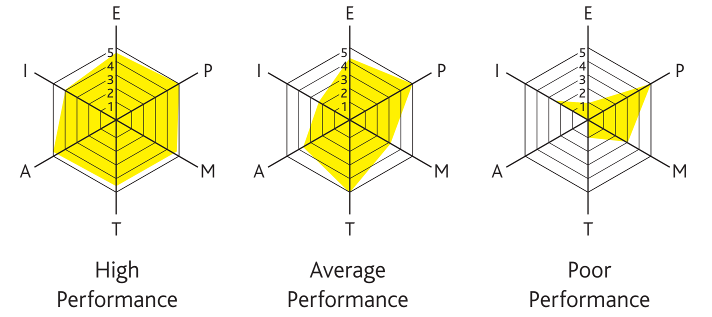
Scherz and her colleagues Liora Bialer and Bat-Sheva Eylon identified how the requirements of the LSS approach – integration of learning skills with instruction about scientific content – requires teachers to make changes to their practice, and in their knowledge and beliefs about teaching, learning and subject matter.[22,23,24,25,26]

As with Ilka Parchmann's research, Scherz has shown how long-term collaboration and sharing of experience amongst teachers is seen as a key feature of the success of the CPD.[27,28,29,30]

A prominent feature of the LSS CPD work is gathering evidence of teachers' experience and learning through the use of teacher portfolios, which Scherz and her co-researchers suggest:

"offer a unique vehicle for self-reflection by exposing 'invisible' aspects of practice to the teacher."

Scherz and her colleagues have employed a diagnostic tool that can be used with the LSS approach, assessing each teacher on six dimensions of professional performance (Fig. 2). The hexagonal representation of teachers' performance can be used to show changes in competencies during the course of a CPD programme and is therefore a useful mechanism for professional self-reflection. Additionally, by analysing the various distributions for each of the performance categories for a cohort of teachers experiencing the same professional development, the diagnostic tool can provide a measure of impact of the CPD programme overall.



P Perception about their acquisition of learning skills
M Practice with regard to their LSS instructional model
T Use of LSS learning materials
A Effectiveness of integration of LSS tasks into studio assessment
I Influence on educational systems
E Reflective skills

Fig. 2. A sample of teachers' professional profiles of Learning Skills for Science (LSS) practice and evidence preparation.

Discussion highlighted the essential role of communities for professional development comprising participation across and within schools, and between teachers, education researchers and professional development providers. Active reflection was once again seen as a the desired outcome and more likely if adopting CPD models comprising 2 or 3-day programmes and intermediate periods to consolidate and implement what they have learned .

Discussants also raised questions about how evaluation of the CPD is seen as an integral part of the process and how it might include focus on beliefs, attitudes and well-being when considering its impact in school.

Further discussion centred on the desirability and feasibility of each approach. Ownership of the process emerged as important, in particular how teachers will respond to a project where the development need is determined by a funding agency or where the researcher is assigned as 'the expert'. Teachers should be involved, at least partially, in identifying the development need. The least acceptable and workable models were considered those where the funders and/or researchers determine the project and where teachers are then recruited.

Reflections in the digital mirror:
The use of video in teachers' professional development

What teachers actually do in the classroom, how they manage learning and how they communicate with their students are the ultimate manifestations of the professional beliefs, attitudes and values they hold. On this basis video has been employed as a means of recording practice and a mechanism for deconstructing teachers' motives, thinking and strategies. The development of more powerful and less intrusive digital technology enables teachers to capture and analyse at a deeper level, as well as providing a much richer source of research data that in turn could lead to greater insight into effective practice.

Traditionally video has been associated with capturing short examples of specific teaching episodes and case studies known as 'microteaching'[31], but the marriage of new technology and more enlightened models of professional learning present new opportunities for greater mutual enhancement. Video remains a tool capable of providing the new entrant and the experienced teacher alike with the opportunity to deconstruct practice in a safe and unthreatening context.

Len Newton, University of Nottingham, noted that there has been little systematic evaluation of the effectiveness of video for teacher development and consequently limited exploration of the various users of video resources.[32] However, Benny Hin Wai Yung, University of Hong Kong, described research that examines the quality of discussion arising from its use. According to Yung and his colleagues Yip, Lai and Lo, the quality of discussion arising from use of videoed episodes of teaching can be seen as a means of engaging teachers in comparing practice.[33]

Software tools such as Interactive Classroom Explorer (ICE), Virtual Interactive Platform (VIP) and *Windows Movie Maker* have presented teachers and professional development experts with new opportunities for analysis of practice and underlying professional attitudes. The software acts as a platform from which users are able to link what is happening in lesson 'delivery' with the learning resources and other features of the work. This might include still images of lesson plans, of whiteboards or students' work located on a lesson 'timeline'. Len Newton and Pete Sorensen have used ICE specifically to help identify:

- the ways in which teachers can work collaboratively to develop their thinking through the use of digital video; and
- the potential the software has to promote such developments and thus improve teaching and learning.

Newton and Sorenson's research made use of ICE specifically with the IDEAS materials developed at King's College London,[34] designed to support the Scientific Enquiry strand of the National Curriculum in England – in particular the development of argumentation.

The study of pre-service science teachers who used ICE showed that their follow-up discussion focused on a range of factors, including:

- students' involvement with and ownership of argumentation activities
- the nature of teachers' questioning and 'teacher talk'
- objective setting
- students' talk and time on task
- students' reliance on peers
- classroom management

The research team concluded that digital video analysis software can enhance professional development amongst teachers and offers a particular advantage over traditional use of video in that professional learners are able to engage with discussion virtually and at a time suited to them.

Their experience has however identified obstacles, some of which could be addressed through professional development provision, as well as organisational factors. These include:

- the time necessary for busy professionals to engage with the software
- technical issues that can undermine commitment
- lack of familiarity with working in this way
- the importance for most, if not all, members of the group to respond and post comments

The choice of video for professional development is a key feature of the work by Yung *et al*. Yung set out to identify the criteria that professional development providers consider when selecting video. These comprise consideration of:

- the associated professional vision
- skills and strategies
- the affective impact of the selected materials and how they are presented
- community and identity aspects

Yung also identified the importance of context and mediation when using video, describing the contrasting experiences of a newly qualified and an experienced teacher. Both were asked to watch "exemplary practices" shown in a video workshop. The more experienced teacher felt empowered by witnessing practice that 'resonated' with his own, whereas the novice described his emotional state as feeling: "at the bottom of a very deep valley." largely for fear of not being able to perform to the same standard. Yung stressed that the use of video can have a powerful emotional effect: "...teacher educators should not take teachers' affective learning lightly. They should not treat the affective outcomes as secondary to the cognitive ones..." [35]

This is, he believes, a reason why the role of the facilitator is so important in guiding teachers through the use of video.

Seminar participants acknowledged that video is a powerful tool with multiple applications for effective learning and teaching. Video encourages teachers and professional development providers to reflect on their practice, and opportunities are greater with the proliferation of mobile devices and open access software.

What is the nature of the relationship between the hardware and the practice of teaching? It was suggested that we have the technology but not necessarily the expertise to exploit it yet. Given the importance ascribed to going beyond the use of video to emulate 'best practice', how might the social and affective domains be taken into account so that teachers are able to make effective use of the technology? Wider discussion reinforced the view made by the presenters that context should be at the forefront of professional developers' thinking when employing video.

There are also ethical issues to address in relation to the use of video generated in class. Equally, participants questioned what qualities a facilitator needs to have to move forward teachers' reflective practice effectively.

A EUROPE-WIDE CPD PROGRAMME?

Matthias Stadler, Leibniz Institute for Science and Mathematics Education at the University of Kiel, highlighted challenges for science education, in particular those faced by countries within Europe, and an EU-funded initiative that attempts to address them. Students' declining interest in careers in the natural sciences, engineering and mathematics is seen as a threat to the economic prosperity of EU countries and to democratic participation.

Science-Teacher Education Advanced Methods (S-TEAM) brings together science and teacher educators from 15 countries. It also develops tested training packages, engages important stakeholders, such as policy administration, teacher associations and parents, and initiates action on a national level.

Despite differences in the resources available, styles of delivery and students' performance in education systems across Europe, representatives from each of S-TEAM's participating countries expressed the same *"low regard for CPD as an effective and successful agent in promoting change in science teaching"*.

Matthias Stadler believes that:

"We know enough about effective CPD to improve the existing professional development systems."

He argues in favour of concerted action, including the establishment of networks of researchers in science education to exchange their national experiences and develop models for effective CPD together.

At the heart of the S-TEAM approach, lies a commitment to 'inquiry-based science teaching', which is characterised as:

"the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers and forming coherent arguments." [36]

Stadler argued that inquiry-based science teaching entails:

- authentic problem-based learning
- hands-on experimental activity
- a focus on autonomous learning and discursive argumentation with peers

and will be reliant on initial teacher education that supports these emphases, and CPD that is embedded in practice and widely disseminated.

SECTION 2

How do we know what works?
Gathering evidence of impact

Evaluating impact of a single teaching intervention is different from assessing the impact of an extended programme of learning. Further challenges to the development of meaningful metrics for teachers' professional development arise from assumptions that are often made between participation in CPD and attainment. Justin Dillon identified how:

"…the complexity of the classroom makes it difficult to infer that changes in student attainment are solely due to changes in a teacher's knowledge or skills resulting from in-service training."

Dillon's perspective echoes the view put forward by the educational psychologist, Thomas Guskey, and referred to by Jeremy Airey of the National Science Learning Centre, that it is complex to interpret evidence [of impact of CPD] because of the variety of factors influencing distal outcomes. Airey reflected on a wide range of questions about the purpose and value of evaluation in relation to professional development.

First he commented on the need to reinforce the integral nature of evaluation within CPD and that the evaluation of CPD:

"…is not an afterthought."

There is therefore a need to ensure that evaluation is integral to, and congruent with, the CPD activities it is assessing. Airey also challenged the tendency to approach evaluation in a formulaic or simplistic way, by asking what is it that is being evaluated and why? Is it to identify differences in practice, to find out what works, to satisfy funders, or to 'self-justify'? The answers to these questions, he suggests, should determine the evaluation methods used and the performance indicators employed.

In order to instill stronger concepts of 'impact' and 'evidence', he also asked whether more effort was needed to develop CPD participants' ability to self-reflect on impact, so that they can make more valid and reliable judgments that can then be used for wider analysis of the effect of the professional development activity. Seminar participants echoed these views, proposing a number of suggestions, including:

- Teachers who are giving feedback for evaluation need to consider the accuracy of their reflection.
- Is there a case for providing guidance for effective feedback?
- How can the CPD and research communities provide teachers with these skills?

"Are we ever going to measure impact in a meaningful way?"

(Justin Dillon, King's College London)

Bob Slavin, Institute of Effective Education, University of York, proposed a radically different take on the evaluation of impact in relation to science education. Slavin believes that education in the UK is moving towards greater devolution at school level over choice of programmes, the nature of the curriculum and teaching methods. Faced with these choices, teachers and school leaders will need to draw upon valid and easy to comprehend evaluation data. He sees 'evidence-based reform in education' as serving this likely need. This approach is a manifestation of the wider evidence-based reform movement that has emerged particularly in the English-speaking world – characterised by the creation and application of practices that produce 'significantly better outcomes', making decisions on basis of best available evidence. Slavin argued that current practice of education is at much the same pre-scientific point as medicine was a hundred years ago:

"We have much knowledge in education, and educators do occasionally pay attention to it, as physicians did in 1910. However, there is limited research evaluating specific programmes, practices or materials, and that which does exist is rarely consequential."

Slavin argued that in order to meet these demands, the following conditions need to be met:

1 There must be a broad range of proven programmes and practices in primary and secondary science.

2 Accessible, impartial reviews of rigorous research evaluations need to be made available for educators and policymakers to be able to draw on to know what has been shown to work.

3 Government must resource the adoption of proven science programmes.

Slavin advocated the use of a competition in which various teams would submit on the design and evaluation of programmes capable of increasing learning and building on what currently exists. He believes that these evaluations should use random assignment, make use of accepted assessments as measures of outcome and feature at least ten schools.

The chain of evidence: Evaluating the impact of the Science Learning Centres

The national network of Science Learning Centres has adopted a model for evaluation of impact that it feels has:

"...significant currency and reflects the different levels that CPD through the network is intended to have."

Mary Ratcliffe, National Science Learning Centre, described how the network's ten professional development centres have adopted Guskey's model for evaluating impact.[37] Guskey notes that evaluation can take place at five levels:

1. Participants' reactions
2. Participants' learning
3. Organisational support and change (impact on school)
4. Participants' use of knowledge and change
5. Learning outcomes for students

Ratcliffe and her colleagues Alison Redmore (Science Learning Centre East of England) and Catherine Aldridge (Catalyst Learning) focused on activity that had demonstrated impact at the higher levels. The network has in place an embedded system of data collection on the effect of courses on the participants' reaction and learning. Ratcliffe identified the challenge of gathering robust evidence on a large scale that is needed to meet levels 3-5 of Guskey's model, which, both in the Science Learning Centres and more generally, has tended towards in-depth studies in specific areas with small cohorts of participants. One such study has been on the impact of school science technicians' course in which detailed follow-up and observation of participants took place.[38]

The network wanted to examine its impact both on a larger scale and at greater depth, and since 2008 has adopted a systematic approach that employs self-reporting and independent validation of change in practice. The approach makes use of the 'impact toolkit', which comprises three forms on which course participants record their CPD progress:

- Initial expectations, including learning outcomes for themselves, their school and students
- An action plan following identification of intended learning outcomes
- Impact of professional development through a record of evidence they have collected focusing on themselves, their students, other colleagues and any impact beyond their own school.

Participants record the type of impact, which can be categorised into the following areas:

1. Skills and knowledge
2. Sharing of learning
3. Change in practice
4. Students' attainment, learning and motivation.

On analysing the completed impact forms, the research team was able to gain insight into the nature of changes at several of Guskey's levels and to examine whether the system of self-reporting is reliable as a means of measuring impact.

The results showed how teachers most frequently (67%) reported gaining skills in the use of new teaching methods, with many reporting they had used these skills in practice (88%) and a similar percentage stating that they had shared their knowledge and understanding with colleagues. Students of teachers attending courses were deemed to have benefited as a result of using materials better matched to the curriculum, were more motivated and had experienced better learning.

Ratcliffe, Redmore and Aldridge are confident that the self-reported impact is attributable to CPD experience. The 'chain of evidence' reported by participants illustrates the development that is taking place attitudinally and professionally. What they are less confident about is the quality of self-reporting in relation to the extent of the impact, which they feel relies on data that needs to be collected systematically and independently, but in collaboration with teachers.

Seminar participants questioned whether accurate self-reporting is a skill that could be developed in teachers, which could be supported through the provision of training and guidance.

Two independent studies have been commissioned by the Science Learning Centres. The first, led by Judith Bennett at the University of York, looked at the nature of teachers' professional change in the classroom, the factors affecting impact and questions surrounding gathering of data for evaluating such impact (Box A). The second study, led by Phil Scott, Centre for Studies in Science and Mathematics Education (CSSME) at Leeds University, set out to probe the impact of focused professional development on teachers' understanding of specific scientific concepts and their associated pedagogical knowledge. It also set out to examine impact, post-CPD, on students' learning of specific scientific concepts (Box B).

In further considering how to evaluate the effectiveness of CPD, points raised in discussion included ensuring that at least some should be long-term and should include some measure of change in perception amongst students. An effective system would draw on a variety of evidence, looking at 'proximal' and 'distal' outcomes, and in a range of developmental domains such as cognitive (e.g. pedagogical content knowledge) and affective (e.g. confidence and well-being) contexts. Supporting a longer-term view, one group highlighted that typically 'performance' initially falls when managing change as a result of cognitive conflict, and that this should be considered when designing and interpreting evaluation data. In relation to generating better self-reported data, it was suggested that a system of external validation of teachers' reflective views would help in making these more robust. More generally the discussants supported the view that success criteria should be clearly embedded in the design of CPD and that these criteria are what any evaluation should assess.

BOX A

The impact of targeted CPD on teachers' professional attitudes and classroom practice

JUDITH BENNETT, MARTIN BRAUND, FRED LUBBEN
Department of Educational Studies, University of York

This study sought to identify how CPD programmes within the national network of Science Learning Centres support primary and secondary teachers in gaining knowledge, skills and confidence to change their practice in relation to key priorities such as contemporary science, new curriculum initiatives and leadership. The research team identified the aspirations of the network, namely to have an impact on teachers' classroom practice, attitudes to CPD, students' experience of learning science and their attitudes towards science both in schools and more widely. The project's findings suggest there is merit in proposing a new model of impact from CPD. Bennett and her colleagues challenged the hierarchical model of CPD impact put forward by Guskey, by suggesting that teachers can effect change in their personal practice without organisational or departmental change within the school. Their research also indicates that though this context for implementing learning from CPD is limiting in terms of impact, it is the most common outcome. For wider impact, they suggest the necessary elements should include support from the school's senior management group, a productive coalition between the head of department and the CPD participant, and the provision of time for the sharing of ideas and training of other members of staff. The production of teacher guides and student worksheets was helpful with such training. The most significant impact was seen where these features were backed up by infectious enthusiasm and authoritative knowledge from the CPD participant.

The researchers employed case studies, purposeful selection of participants and interview data from participants and those responsible for deciding on the CPD for the teacher to discover:

- What is the nature and extent of teachers' professional change in classroom activities as a result of participating in selected CPD programmes offered by the Science Learning Centres?
- What are factors facilitating and/or hindering such classroom impact of selected CPD programmes?
- What are the issues affecting the feasibility of gathering reliable and valid data on the classroom impact of teachers' participation in selected CPD programmes?

Focusing on two of the intermediate levels of Guskey's model 'Organisation support and change in the school' and 'Participants' use of new knowledge and skills' the researchers examined whether Guskey's levels are hierarchical and-therefore is achieving a lower level a necessary condition before attaining a higher one?

BOX B

Impact of focused CPD on teachers' subject and pedagogical knowledge and students' learning

PHIL SCOTT, JAUME AMETLLER, ANDREW EDWARDS

CSSME, School of Education, University of Leeds

The second independent Science Learning Centre-commissioned study looked at the impact of focused CPD on teachers' understanding of specific concepts and pedagogical knowledge and examined impact on students' learning of specific scientific concepts. The research team attempted to identify conceptual and professional knowledge changes taking place following participation in long-term professional CPD for non-specialist teachers of physics and whether their enhanced skills and knowledge had any effects on students' learning about those concepts.

Data on teachers' understanding was collected before and after the first CPD course and immediately after the second course. The two courses took place approximately five months apart. In addition, teachers reported on the approaches they took in teaching the topics and administered a set of key learning questions, which they could use in one of two ways. If some classes had been exposed to the new teaching methods while others had not, the questions could be used to make comparative assessments of impact. Alternatively, students answered the questions before and after having been exposed to the new approaches.

The concepts that had been taught are those that are traditionally misunderstood or misinterpreted by non-specialist teachers, including (i) use of forces arrows and the direction in which they act; (ii) force and motion; and (iii) teaching and learning about gravity.

The key learning questions were designed to test the participant's/student's conceptual understanding and to assign a score according to the quality of the response. A significantly flawed (incorrect) statement was assigned a score of 1. Where the answer contained some aspects of a correct response (partially correct), the response was awarded a score of 2. For a fully correct answer, a score of 3 was given. For Fig. 3, the scoring would correspond to the following:

Incorrect: no upward force from the table shown.

Partially correct: two forces correctly shown but no indication that the forces are of equal size.

Fully correct: two equally sized forces correctly shown.

A little penguin, Percy, is sitting on a table.

- Draw in the forces acting *on the little penguin*
- Fully label each force you have drawn

Explain why you have drawn the forces in this way:

Fig. 3 Example of key learning question.

The table below shows for a given teacher ('Nancy') how many of her students improved or maintained their correct or partially correct understanding (pale blue shading) of the four forces and motion concepts. For the penguin question, seven out of eleven students improved or maintained their understanding. For this question, the teacher's own understanding was high as indicated by the 2-3-3 score corresponding to their conceptual grasp at the three CPD junctures. However, her lower conceptual grasp in the 'Ball' question (not shown) may be a significant factor in the comparatively low scoring of her students for this particular concept (only four improved or maintained at least some degree or understanding).

Teacher N	1-3-3	2-3-3	1-2-3	1-2-2
	Climber	Penguin	Skater	Ball
Pupil Pre-Post Profiles				
1-3	3	3	3	2
2-3	2	1	1	1
3-3	2	1	1	0
1-2	2	2	2	1
2-2	1	0	0	0
2-1	1	0	0	0
1-1		4	4	7
	10/11	7/11	7/11	4/11

Fig.4 Table of pupil pre-post test scores for conceptual understanding of aspects of forces, motion and gravity.

Emerging findings demonstrated evidence of sustained enhanced learning across a disparate group of 15 teachers and further evidence of student learning. This has led the research team to make the statement:

"We have here clear evidence of impact on teacher and student learning of the Science Learning Centre course in relation to a fundamental aspect of Newtonian mechanics. It is thought provoking to say the least to consider that prior to attending the course, Nancy was in no position to help her students in this area of Newtonian mechanics, simply because she shared the same erroneous 'commonsense-thinking' starting point. Furthermore, this tangible change in practice was achieved after a CPD intervention lasting just 5 hours."

The use of journals and portfolios to evaluate effective practice

This session commenced with two presentations exploring how research tools can be used to make professional development for science teachers more effective, and through which assessment of impact can be made.

The first made use of a logbook which elementary teachers used to document and reflect upon their plans, actions and outcomes. Claudia Fischer and colleagues at the Leibniz Institute for Science and Mathematics Education at the University of Kiel (IPN) have analysed the logbooks' contents – verifying coding across a number of researchers acting independently. This verified data showed how teachers engaged in the programme adopted a problem-oriented approach, related their reflections to objectives and focused on the development of teaching methods and resources as the main route to better learning.

The SINUS programme is the largest and most innovative programme aimed at improving school effectiveness in Germany. SINUS started in 1998 in German secondary schools, in response to findings from TIMSS (Trends in International Mathematics and Science Study) which reported on the poor performance of teenagers in Germany in comparison to other countries. The long-term professional development programme was funded by national and federal government and continued as a common programme until 2007.

Fischer and her colleagues set out to investigate how well SINUS was able to contribute to professional development process in elementary schools and within three domains:

1 The degree to which teachers work in a problem-oriented manner in either mathematics or science, including how well they were able to construct their own objectives and reflect on their actions.

2 Their capacity to adapt to the task of improving classroom instruction, developing teaching methods and working out examples of good practice.

3 How effectively they were able to develop stable professional relationships through the programmes that were derived from its objectives and their reflection.

The main instrument used to evaluate impact was a logbook, broken down into two segments documenting (i) objectives and (ii) actions, experiences and reflections. All participants in the programme were expected to maintain a logbook for the duration of their involvement. In 2006, 2007 and 2009, 174 randomly selected schools were asked to submit these records for assessment. The research team employed a range of qualitative methods to analyse the highly heterogeneous material – ranging from students' work to letters to parents. The data were authentic, in that what was reported usually reflected what had taken place. Three or four researchers independently assessed the logbooks and, by using criteria developed for the secondary school programme, were able to demonstrate 90% reliability across coders[39,40].

The assessment showed how SINUS moved teachers from simply reporting actions to a greater focus on a specific subject and, with reference to objectives, attempting to solve a defined problem. The logbooks show greater cycles of planning, acting and reflecting, as the project progresses, the importance of the development of teaching materials in contributing to the programme's overall aims and how professional cooperation requires significant time and support.

The SINUS scheme made use of journals kept by a large sample of experienced teachers to assess the degree of change in practice by teachers.

A smaller scale study was carried out at the University of Washington to examine the value of using a portfolio of student artefacts to analyse science teacher practice amongst groups of pre-service teachers – thus embedding what the team describes as "*collaborative inquiry into student thinking*", at the earliest stage of teachers' professional experience. Mark Windschitl, who led this work, set out to identify whether pre-service teachers could improve their initial practice through use of specially designed analytical tools to support collegial critical analysis. [41]

The scheme drew on four aspirational elements of effective instruction, referred to as 'ambitious practices':

1 Selecting big ideas

2 Working with students' ideas

3 Investigating science ideas in the classroom

4 Pressing for explanations

The study focused only on the fourth ambitious practice *pressing for explanation* – collecting examples of student work that might typically indicate a progression in understanding through explanations from (i) observation of a relationship between variables, through to (ii) student discourse of that relationship and finally arriving at (iii) a generalised causal explanation for the phenomenon.

This work was an extension of research into the impact of a scheme to support newly qualified teachers. Windschitl suggested that despite mentoring and personalised support, the novice teacher experiences isolation in these early years, which leads them to adopt "*a survival mentality*". By bringing together recent graduates from their teacher education programme to work collegially, discussing and examining their students' work, the scheme shifted the focus of the first teaching year away from survival towards inquiry and growth.

The novice teachers analysed student-generated materials and generated hypotheses between their own practice in class and the quality of learning demonstrated through the range of artefacts presented, including written responses, drawings or video of conversations, amongst others. Collegial analysis of student work had been shown to contribute to improved student learning,[42] helping teachers to generate and test hypotheses about instructional decisions[43] and pushing them to think beyond routine activity.[44]

Participants in the study had been enrolled in postgraduate teacher education programmes in major research universities in the USA and had been exposed to a 'methods' course in the earlier part of their education studies, in which they were introduced to the four elements of ambitious practice. They were then placed in teaching practice schools during which they were directed to collect samples of student work early on, midway through the practice and at the end. The samples reflected three categories of student according to the ease with which they were deemed to learn new ideas. On return to university, the participants employed rubrics designed by the research team to help analyse student work around the facets of model-based inquiry.

Research findings demonstrated that teachers in pre- and early service can benefit from this approach – with some developing 'expert-like' classroom performances. A key factor was identified based on the influence of the participants' underlying theories of teaching and learning – with those possessing a more sophisticated view about the complexity of learning and teaching – presented as what are described as 'puzzles of practice'. It was those teachers with a problematised view of the relationship between teaching and learning who have been shown to benefit more from the evidence-based collaborative approach and to engage early in more skilled teaching.

Seminar discussion highlighted what these two approaches – logbooks and portfolios – shared in common and their differences. How a teacher uses an analytical tool is conditional on their self-awareness and beliefs they have about teaching and learning. Linked to this was a question about how teachers could be encouraged to retain a disposition towards critical self-reflection as they move through their careers. This suggests that reflective practice requires a good deal of expert support and collaboration which has implications for the style of delivery and

		More sophisticated →			
		Level 1: No press for explanation Situation exists for teacher to ask students to explain phenomena, but teacher by-passes opportunity.	**Level 2: "What happened" explanation** Teacher asks students to provide a description of a phenomenon or thing, or may ask students to put into words a scientific correlation.	**Level 3: "How/ partial why" explanation*** Teacher emphasizes a scientific correlation and how it helps a system work.	**Level 4: Causal explanation*** Teacher asks students to use theoretical processes to construct causal story of what happened. Teacher unpacks/scaffolds "what counts" as a good scientific explanation with students.
TL Problematic	**Simon**		○	○○●●	●●●
	Rachel		○	●	○○●●●●
	Sarah	○●	○●	●●	●
	Barbara		○●●	○●●	○
	Amanda	○○●	○●●●	●	
In Transition	**Emily**	●	○○○●	●●●●	
	Elena	○	○●	●●	
TL Unproblem-atic	**Luke**		○○○○●●		
	Kelly	●	○○●●		
	Patricia	○●	○●●●●	○●	
	Adam	●	○○○○●●●	●	

Fig. 5 Teachers' appropriation of instructional strategies

resourcing. Equally, collaborative professional discourse as a key element in successful CPD will help teachers to see professional development as valuable, in that it is "*something they do rather than something that is done to them*". And could the performance progression illustrated by Mark Windschitl (Fig. 5) be used as a way of indicating progress in CPD more generally?

Some participants questioned the sustainability of these two approaches to professional development, though observations were made that while both schemes have a clear lifespan, each will leave a residual effect.

An example of this might be the valuable experience in bringing teachers back into university early in the careers and the benefit of links existing between pre-service and newly qualified teachers.

One of the big issues facing professional development in science education in England is how it can be brought together with mathematics, technology and engineering, under the STEM umbrella. Justin Dillon had asked at the start of the seminar: how serious is the commitment to STEM in terms of links across these individual subjects? – The implication was that major changes would need to be implemented for real STEM education to be effective. But could tools be employed to help teachers, researchers and professional development providers look across disciplines?

What next? Outcomes from seminar discussions

Seminar participants proposed strategies for ensuring that the environment for professional development continues to grow and that high-quality CPD becomes embedded in schools' thinking and planning. High-quality CPD was felt to improve the quality of teaching and learning, promote student engagement and motivation, and contribute to teacher retention. The following set of principles and actions was proposed to help guide the science CPD community in furthering its future development:

- Collaboration between teachers, professional development leaders and researchers has the potential to be very productive in supporting professional development which has impact on practice.
- Professional development experts occupy a niche as mediators of new ideas and emerging research. Positioned between academic research and classroom delivery, their role can be to guide teachers at all stages of their careers, employing research findings to promote autonomous reflective practice and brokering the relationship between all the participants in the process.
- CPD works best when it takes place over time, punctuated with opportunities to reflect on, and apply, the ideas under consideration in a school setting.
- Sustained reflective professional practice is more likely to arise if there exists a collegial approach to professional development.
- Fruitful and productive reflection on practice is often stimulated by the perspectives that researchers familiar with the literature, and others working outside the classroom, can bring to the CPD context.
- It is important that CPD enables teachers to learn from their own and others' practice.
- A culture of reflective professional practice should be instilled pre-service, and continue throughout a teacher's career.
- There is a need for a diverse repertoire of approaches to CPD, including those which start small but can be rolled out on a larger scale.
- Engaging teachers in curriculum development is often an effective means of professional development.
- Modern technology, when used intelligently, can provide access to examples of practice in a manner that stimulates individual and collaborative reflection. Its potential should be more thoroughly explored.

What are the challenges and what needs to be done?

Participants acknowledged the challenges that are to be faced, and the complexity of the environment in which CPD takes place. A significant amount of work is required to ensure that professional development meets the needs of the science education community.

Effective CPD may mean something different to teachers, government, funders and CPD providers and education researchers. The various stakeholders may demand a range of impact measures over different timescales.

Derek Bell of the Wellcome Trust drew on the emerging messages and summarised what needs to be done to meet these and other challenges for the Science Learning Centres and the wider science CPD community:

- **Clarify the message**: Both the research and CPD communities must communicate clearly with policymakers, making use of robust evidence of outcomes of CPD to inform policy developments related to high-quality professional development.
- **Build alliances**: Go beyond developing networks to build strategic relationships, nationally and internationally.
- **Agree priorities**: For example, identify some key pedagogical principles that should be placed at the centre of teacher education.
- **Refine the evidence base**: Attempt to develop a unifying model for evaluating impact.

List of participants

Dr Jeremy Airey	National Science Learning Centre
Dr Ian Abrahams	University of York
Professor Derek Bell	Wellcome Trust
Professor Judith Bennett	University of York
Dr Amanda Berry	Monash University
Bryan Berry	Science Learning Centre South West
Dr Stuart Bevins	Sheffield Hallam University
Sheila Curtis	Science Learning Centre London
Dr Carol Davenport	Science Learning Centre North East
Professor Justin Dillon	King's College London
Dr Claudia Fischer	Leibniz-Institute for Science and Mathematics Education (IPN)
Jo Flynn	Science Learning Centre West Midlands
Dr Marcus Grace	University of Southampton
Professor Jan Green	Manchester Metropolitan University
Dr Janice Griffiths	Science Learning Centre South East
Dr Hazel Healey	University of Keele
Caroline Hurren	Science Learning Centres
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Dr Irina Kudenko	National Science Learning Centre
Andrea Mapplebeck	National Science Learning Centre
Professor Robin Millar	University of York
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Rosalyn Sands	Science Learning Centres
Dr Zahava Scherz	Weizmann Institute of Science
Professor Phil Scott	University of Leeds
Professor Shirley Simon	Institute of Education, London
Claire Simpson	Science Learning Centre East Midlands
Professor Robert Slavin	Institute for Effective Education, York
Amanda Smith	Science Learning Centre North West
Dr Matthias Stadler	Leibniz-Institute for Science and Mathematics Education (IPN)
Miranda Stephenson	National Science Learning Centre
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Dr Maarten Tas	University of Leicester
Jane Turner	Science Learning Centre East of England
Professor Jan van Driel	University of Leiden
John Wardle	Science Learning Centre Yorkshire and Humber
Professor Mark Windschitl	University of Washington
Dr Jocelyn Wishart	University of Bristol
Dr Benny Yung	University of Hong Kong

Seminar Programme

What do we know about effective CPD in science education?

Session 1: **Effective CPD for developing pedagogic content knowledge**
Presentations: Jan van Driel, Amanda Berry
Discussants: Jan Green, Amanda Mapplebeck
Chair: Caroline Hurren

Session 2 **Effective CPD using video material/ online aspects**
Presentations: Benny Yung, Len Newton
Discussants: Jocelyn Wishart, Richard Needham
Chair: Marcus Grace

Session 3 **Effective CPD using a project-based approach – communities of practice**
Presentations: Ilka Parchmann, Zahava Scherz
Discussants: Alison Redmore, Fani Stylianidou
Chair: Ian Abrahams

Session 4 **Putting effective CPD into practice – How can we build capacity and leadership in development of effective CPD?**
Presentation: Shirley Simon
Chair: Robin Millar

Session 5 **International approaches to professional development**
Presentation: Matthias Stadler
Chair: Miranda Stephenson

What do we know about methods of, and approaches to, understanding the impact of CPD?

Session 6 **Changing teachers' practice – outcomes of different scales of approach**
Presentations: Claudia Fischer, Mark Windschitl
Discussants: Jo Flynn, Stuart Bevins
Chair: Carol Davenport

Session 7 **How do you evaluate the effectiveness of CPD?**
Presentations: Bob Slavin, Mary Ratcliffe
Discussants: Bryan Berry, Jeremy Airey
Chair: Janice Griffiths

Session 8 **What methods and approaches should we use to evaluate and to understand the impact of CPD? Two contrasting approaches in progress**
Presentations: Phil Scott, Judith Bennett
Chair: John Wardle

How can we build capacity and leadership in development of effective CPD, particularly in relation to early career professional and career progression?

Seminar plenary

Implications for practice, policy and research in building capacity
Chair: Derek Bell

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TAP1165/23-06-10/V4