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Bowland Maths Lesson Study Project

Report

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Bowland Maths Lesson Study Project: Report

Executive Summary

The Bowland Maths Lesson Study project was designed to introduce new methods for professional development of secondary school mathematics teachers by adapting a Japanese Lesson Study approach; it was implemented in nine schools during 2012-2013.

Background

The Lesson Study approach was first established in Japan over 100 years ago and is increasingly being used in other countries, particularly Singapore, but also in the US – and now in England. It is a method of classroom-based professional development, built round 'research lessons' that are planned by a team of educators and delivered by one of them. The research lesson is designed to explore ways to improve students' learning, with the students being closely observed by the rest of the team – and often also by other invited teachers and experts. A post-lesson discussion is conducted, immediately after the lesson, in which the team and the observers discuss their observations of the students' learning and explore ways in which the lesson could be planned better to further enhance their learning.

It is a powerful method, which can lead to 'systemic' improvement, with teachers, academics, teaching advisors and material designers all learning, within a professional grouping. Capturing the full power of Lesson Study is not easy. Different adaptations around the world have been made to 'suit' the local environment, but maths education experts in Japan have been increasingly concerned that many of them have neglected some key principles and so have failed to benefit fully from the approach. The Japanese government launched an international project (IMPULS) to help establish global good practice, mobilizing Japanese maths education experts for the task.

Bowland Maths has been fortunate in developing close working relations with the IMPULS team over the last three years – pre-dating this project. This started from a Japanese interest in Bowland, which they saw as an innovation of interest to Japan. The result has been a rich collaboration, with Japanese experts joining the project team for half the research lessons in this project.

This report summarises the project in terms of its design, implementation arrangements and outcomes. To ensure that the report is as objective as possible, the views of participants were monitored and collected throughout the project, as in 'action research'. The data collected included: observations of 17 of the research lessons; feedback from participants (teachers and experts), from visiting Japanese experts and from non-project observers; 21 formal interviews; two surveys of all participating teachers, one conducted before and one after the project (with c.65% response rate).

The main objective of the report is to extract lessons from the project to clarify:

- the nature of the benefits that Lesson Study can bring
- the essential design features needed to maximise such benefits
- possible next steps and lessons for the future

What were the main conclusions about benefits?

The experience of this project went well beyond its original expectations – to explore Lesson Study as a way to help individuals with their own professional development. One major outcome was that the vast majority of the participants, teachers and maths education experts alike, now strongly believe that Lesson Study is a powerful approach to professional development which would produce real benefit if it were more widely established for teachers of maths in England.

But the project has shown that the practice of Lesson Study can contribute more than to the professional development of the teachers involved. It can also operate as a (much needed) mechanism to link university researchers directly to classroom teaching; in fact, the project has shown that the use of the Lesson Study can help create an effective network of maths education professionals (teachers, academics, practitioner advisors, material designers), built round classrooms, which can then develop well informed views about ways to improve student learning.

The project has also shown that Lesson Study can be a powerful demonstration and diffusion mechanism for classroom innovations – both for new teaching materials and for new pedagogical approaches: there was a significant subsequent uptake of Bowland Maths materials in participating schools – and a common reaction from outside observers was "I would like to try this lesson".

Lesson Study events can also provide valuable feedback from classrooms to education material designers to help them to improve teaching materials: any education material designers who participate in research lessons gain good insights into student learning – as happens in Japan.

None of these benefits is 'automatic': considerable effort was needed throughout the project to develop the approach so that it could reap such benefits – and more work is needed to improve this further.

What were the outcomes?

The results of the project were a positive surprise to all the participants. The teachers and the maths education experts became so enthusiastic that they decided to explore ways to continue with some form of Lesson Study in the future – well beyond the funding of this project: as at autumn 2013, seven of the nine participating schools were developing specific plans to continue with Lesson Study, even with no further external funding. The participants also became clearer about the impact of problem solving on student learning and all nine schools are taking steps to regularize the use of Bowland Maths materials, most of them within revised 'Schemes of Work'.

The expert team at Nottingham University has successfully applied for additional funding (from the Nuffield Foundation) to develop a sustainable model of Lesson Study for problem solving, ie one that would require no external funding. Several other advisors are also seeking new sources of funding for further work. Many of the invited external observers also expressed great enthusiasm for using Lesson Study in the future - and for making more use of Bowland Maths materials.

Why was there such enthusiasm?

At the core is the conviction of participants that 'this works' as Professional Development. Every one of the responding participants – teachers and experts – rated the experience as valuable for their own professional development, with the overwhelming majority of teachers (more than 60%) also saying that this was one of the richest professional development experiences they had ever had. Teachers also valued the opportunities to collaborate closely with colleagues, with the result that they are now able to have much better professional dialogues on a day to day basis. They found the feedback from the Lesson Study event valuable and relevant, as it was about *their* lesson and their classroom – and not some abstract lecture or workshop (in which points are often hard to translate into practice). Teachers thought that they are now better equipped to focus on student learning and also better equipped to prompt it.

The project also helped teachers to improve their own knowledge of problem solving and teaching process skills: the more experienced teachers developed detailed insights into process skills and the progress that students can make; less experienced teachers learned the value of problem solving and developed the confidence to deliver problem solving lessons. The critical point is that all the

teachers thought that they had learned something important and, as a result, that they improved their own professional practice.

Teachers (including those for whom Bowland Maths was new) and the maths education experts converged in their conclusion that it is good practice to use context rich problems such as Bowland Maths materials on a regular basis – the majority suggested one such lesson every two to three weeks, perhaps also with project work each term. They thought that this would not only enhance student motivation about why and how maths is useful in life, but would also promote a deeper understanding of mathematical concepts and processes. They agreed that most Bowland materials can be useful for all ability groups, albeit with some modifications.

There is now a much greater array of mathematical problems available as teaching resources than when Bowland Maths started. Within this set, participants still thought that the Bowland materials were unique in terms of being reliable, open and context-rich resources, fun for pupils and bundled with helpful teacher resources such as lesson plans, student progression grids and sample student responses. The usability of the Bowland materials for Lesson Study can be improved further, of course, and various participants provided ideas about how to do this, based on the experience of this project.

What were the key design features of the project?

Much of the success of the project derived from the model of Lesson Study that was developed, by interpreting 'best practice' from Japan, but designed *with* the Japanese team. Perhaps the most important design point was the use made of a range of external experts in maths education. *Research academics* made a major contribution by pushing the lesson planning to a higher level by asking critical questions about process skills – for which the pedagogical issues were unclear. Contributions of practitioner advisors contributions were as important and complementary, as they offered pragmatic solutions for immediate improvements in classrooms; these included local authority advisors, private consultants and university ITE staff.

Each type of 'external expert' played different, but complementary roles, operating as a networked group of teachers and external experts. In this way, the approach pushed teachers to have a clearer focus on investigating how to improve their own teaching practices and so be able to tackle cutting edge issues in problem solving.

It was also important to have a well established structure for the discussions, with clear roles and expectations about what the *discussion chair* and the *expert commentator (Koshi)* should do. The role of *Koshi* was particularly important to ensure that the benefit of the research lesson was generalised to an extent and more widely shared, not only for the Lesson Study team, but also for the external visiting observers.

What should be the next steps?

The Bowland Maths materials were the genesis for this unique and rich collaboration with Japanese experts, which has made this a 'one-of-a-kind' Lesson Study project. In future efforts to embed Lesson Study as a professional practice in England, it would make sense for teachers to use the range of materials now available, including those of Bowland, from which to select research lessons. However, the experience of this project strongly suggests that the materials selected need to be of high quality if valuable Lesson Study opportunities are not to be wasted.

It is extremely fortunate that the Nuffield Foundation, with whom Bowland Maths has had direct collaborations in the past, is now funding the subsequent development of a sustainable approach to Lesson Study for professional teacher development in problem solving. It is doubly fortunate that

this is to being undertaken by the Nottingham University team who have been a mainstay of Bowland Maths from the outset.

Meanwhile, if funds permitted, a follow up task for Bowland Maths would be to revise some of its teaching materials and professional development modules to make them more directly usable for Lesson Study. This would help ensure that the emerging Lesson Study community would continue to have access to good quality teaching materials to help them break new ground.

What are the lessons from this project?

There are two critical points that would help to develop Lesson Study as sustainable professional practice: a 'supply side' point and a 'demand side' one. It is to be hoped that the new Nottingham University project being funded by the Nuffield Trust will explore both these aspects of the future.

On the 'supply side', there is a need to find ways to ensure the supply and involvement of a diversity of 'external experts' in Lesson Study events – from at least three different sources. First, because problem solving and the teaching of process skills is one of the least well developed areas of maths education in England, it is important that future Lesson Study events should continue to involve research active academics. Equally, the involvement of ITE teaching staff is important to ensure that there is an inflow of new teachers trained to see Lesson Study as a routine tool for their own continuing professional development. Third, a valuable role is played by practice-oriented advisors and experts – from either private or not-for-profit organizations. Some of these external experts, from any of the sources, also need to develop the capacity to perform the expert commentator role (Koshi) to raise the level of collective learning in Lesson Study events.

On the 'demand side', there is a need to find ways that persuade schools that the resources required for Lesson Study (mainly the costs of external experts and of teacher cover) are good value for the school in terms of the professional development of its maths teachers. This is critically linked to there being an adequate (supply side) capacity of external experts/visitors/commentators to raise the level of discussion at Lesson Study events.

The national context is now right for schools to increase their teaching of problem-solving and their use of context based problem solving materials, such as those from Bowland, and explicitly introduce them into their Schemes of Work. Schools as well as teachers are now more aware of the need to include lessons with context rich problem solving, partly because of the new curriculum's continued emphasis on it, but also because of the increasing use of such problems in exams. There is also a well-recognised need for the development of new models for the professional development of teachers. The experience of this project should provide a key step for ways forward.

BOWLAND MATHS LESSON STUDY PROJECT: Report

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1. INTRODUCTION

The Bowland Maths Lesson Study project was a one-year project for secondary mathematics development, designed to introduce professional development of teachers and to improve Bowland Maths materials, through adapting a Japanese Lesson Study approach. Lesson study is a classroom-based professional development method with an explicit focus on student learning. Lesson study is designed to improve teaching and the teaching materials used in classrooms, through collaborative lesson planning, lesson observation and collective reflection. It is a powerful method, first established in Japan, which is increasingly being used in other countries, such as Singapore and the US.

The idea of the project first arose during a visit by Bowland Maths experts to Japan in February 2012. The Japanese mathematics experts, who had been working with Bowland Maths for some time with the aim of introducing something similar in Japan, used 'lesson study' to demonstrate how Bowland Maths and similar teaching materials were being introduced in Japan. Their intension was to obtain expert advice from the UK team about Bowland maths. The UK team was struck by the high level of grasp and fluency that average students appeared to have in mathematics in Japan, but they were particularly impressed by the power of 'lesson study' as an approach for collective thinking on classroom practices, involving teachers, university and other maths education experts. They could 'see' why and how good teaching and good teaching materials could result from 100 years of practicing lesson study nationwide. They could also see in the Lesson Study Approach, a possible 'answer' to the critical issue of professional development, which was increasingly seen to be a key bottleneck for Bowland Maths – and for teaching problem solving skills more generally.

The timing could not be better for collaborative work with the Japanese maths experts. A group of 15 Japanese maths experts were working together to introduce Bowland type teaching materials into Japan, funded by the Japanese government. The leader of that group was also a key member for another new project, also funded by the Japanese government, to promote globally best practice in Lesson Study. The Bowland Maths Lesson Study Project was quickly planned, with a project launch workshop in July 2012, to be implemented in 2012-2013.

1.1 Basis of this report: Data and methods

This report summarises the experience of the project in terms of its background, objectives, design, implementation arrangements, outcomes and the lessons for the future. The data on teacher and advisor responses were collected throughout the year in a manner of action research: (a) through 17 research lessons, where lessons and discussions were observed, and feedback was actively sought from teachers, experts, visiting Japanese experts and outside visitors; (b) through interviews with nine teachers conducted by external advisors; (c) twelve in-depth and recorded interviews with leading teachers and project core experts; and (d) and two surveys of all participating teachers conducted before and after the project to capture their views and experience. Sixteen out of the 24 teachers responded in these surveys, making a response rate of 67%.

1.2 Background: Bowland Maths

The starting point for the development of Bowland Maths was an open question by a philanthropist – why is it that Britain is not better at maths? Its early analysis led to a finding that there was a major issue in student interest in maths through ages 11-14, when many students lose interest in maths. KS-3 is a critical period when mathematical content becomes more abstract and students find it harder to see how it can be relevant in life. Bowland Maths' response was to introduce teaching materials that are engaging and context rich – so that students could develop interest in maths, see that it was fun and see that it had a clearer sense of purpose.

The first step was to develop a series of 'case studies' using rich contexts to make mathematical problems more interesting and/or relevant, with an emphasis on open-ended problems that required a range of process and problem solving skills to solve. This emphasis on process skills combined with a pioneering push to make maths more engaging for students, was consistent with the views of maths education experts at the time, and was instrumental in reinforcing the new national curriculum and strategies to emphasize key processes in 2008.

The second area of emphasis for Bowland Maths has been professional development of teachers. It was clear from the early days that to use the case studies effectively, or more generally to teach key processes better, teachers needed new pedagogical skills. To make professional development opportunities more 'accessible' for all teachers, interactive video resources for professional development were developed.

The third component of Bowland Maths step was to develop some shorter 'assessment tasks', published in 2011. The original aim of these shorter 'problems' was to illustrate to maths education experts and teachers what kinds of questions could be used as tests to assess student mastery of key processes. The motivation was to change exams, which were seen as the biggest stumbling block for curricular change on the ground. Each of these assessment tasks was developed, illustrated by samples of student work as well as a 'progression grid' which demonstrated how student progress in process skills could be measured. Subsequently, exams began to include more problem solving, which is becoming one of the key drivers for teachers to use problem solving in their teaching. The assessment tasks have since been 'discovered' by teachers as excellent teaching materials, combining simple questions with pioneering resources such as the student responses and the progression grids which are helpful for teachers to plan their lessons.

The Bowland Maths materials now comprise 27 full Case Studies, each requiring 2 to 5 lessons, 35 Assessment Tasks, each requiring 30 minutes to an hour, and seven Professional Development Modules, each requiring about 3 hour's work for a teacher. These are all available on the Bowland Maths web site (www.Bowlandmaths.org) and many of them are also on the Bowland DVD, five copies of which were sent to all secondary schools in England in 2008.

The initial feedback from teachers, from maths education experts - as well as from pupils, has been very positive. However, beyond the initial launch, effective diffusion of the materials has not been easy. The key issue appears to have been that Bowland Materials were perceived as not easy to use by teachers. Many teachers found problem solving not easy to teach – let alone open ended questions. Professional development was essential and yet individual teachers did not themselves see the need for it. The little time they had, they would spend in preparing specific lessons rather than in going through any of the professional development modules. Bowland Maths's professional development modules, whose quality is attested by the fact that they have since been adapted for the European Union through EU-funded projects, remained – and remain, underused. Many teachers also felt that they did not have the time to explore Bowland case studies fully – to select or adapt them for their classroom use. It would have been ideal for them to see the materials being used in class – but such opportunities were not available. Nor was it easy to fit the multiple lessons that cases required into their scheme of work. The period of uncertainty about curriculum direction in the last couple of years also placed a heavy damper on enthusiasm for teachers to adapt new approaches; now, with a clearer national direction, the need for problem solving and process skills is again being embraced by the teaching community. But something more than a curriculum change and national direction was needed to prompt teachers to embrace the needed professional development. After 4 years, it was also timely to consider improvements to the Bowland teaching materials themselves, to make them more accessible and usable to teachers.

The Bowland Lesson Study Project was conceived because the Lesson Study approach to professional development appeared to address all the key issues that Bowland Maths had encountered in its past efforts: a lack of a powerful approach to PD for process skills, a lack of

demonstration/diffusion mechanisms for innovative ways of teaching, and a lack of a mechanism to systematically improve teaching materials based on practice.

1.3 Background: Lesson Study

'Lesson Study' (LS) is a professional practice which has been used by Japanese teachers for over 100 years to improve the quality of teaching – through the professional development of teachers as well as the improvement of educational materials – and hence to enhance student learning. Lesson Study is in essence 'collaborative research' amongst groups of teachers, usually from one school, often with one or two participating outside experts. The idea is for a group of teachers to identify a issue that they would like to tackle together in terms of teaching, and to conduct a 'research lesson' which is observed by the research team as well as others, and then to draw conclusions about what improvements could be made in pedagogy and/or the educational materials to ensure more effective learning by students. It could be viewed as an amalgam of action research, teacher development and materials improvement.

The format of Lesson Study is well established in Japan in that any one teacher today might typically 'deliver' one or two Research Lessons in a year, but observe, and learn from, about 10-20 other Lesson Study events. Lesson Study was instrumental in diffusing the now widely used practice of using 'problem solving' in maths education in Japan, particularly in primary schools. Many Japanese maths education experts believe that Lesson Study has been at the heart of Japan's success in maths education - which also includes excellent textbooks that introduce key mathematical concepts in a carefully thought through sequence by means of a well tested set of maths problems.

There has been increasing interest internationally to adopt Lesson Study as a practice elsewhere, with a recent surge, especially in the USA. About 7 years ago, Singapore adopted the LS approach where it is now used in about 70% of its schools. Partly as a response to this new interest, but partly because Japanese maths experts were increasingly concerned that many international replication efforts had resulted in 'watered-down' versions of Lesson Study, the Japanese government decided to sponsor a project called the International Math-teacher Professionalization Using Lesson Study (IMPULS) to promote the concept of Lesson Study abroad.

1.4 Background: Japanese interest in Bowland Maths

In Japan, a group of maths experts advising the Government on curriculum, developed a sustained interest in Bowland Maths. This is because Bowland Maths materials – particularly the case studies - cover a critical aspect of mathematics which they consider to be missing in Japan. While problem solving is used actively and routinely in maths education in Japan, most problems are purely mathematical ones, with only a thin disguise of 'contexts'. There is little curricular emphasis on learning how to *apply* maths to the real world or in open-ended and complex problems. Further, the Japanese students score particularly low in international comparison in terms of their enthusiasm or interest in learning maths. The expert view is that there is a real need to teach maths in a way that is context-rich and engaging – a situation similar to that of the UK. When some of the Japanese maths education experts saw the Bowland Maths case studies, they could see what they were missing.

The Japanese team first contacted Bowland Maths in 2010 to request that they visit UK schools to see Bowland Maths in action. Immediately after that, they started exploring Bowland Maths materials for Japan and the possibility of developing Bowland style teaching materials through Lesson Study. In February 2012, they invited a four-person Bowland team to Japan to advise them how best to introduce Bowland Maths in Japan and asked them to participate in their Lesson Study. This was the first time the Bowland experts had seen Lesson Study in action; it did not take long for the two sides to realise that there was a common interest: to create an environment in which

teachers and experts can actively collaborate to develop teaching skills and Bowland type materials for process. Within a month, the blueprint for a Bowland Maths Lesson Study Project was developed in England and shortly thereafter agreed by the funder. In June 2012, one teacher and a university expert from the UK were invited to Japan to join a two-week IMPULS immersion programme to learn more about Lesson Study. In July 2012, the teams of teachers identified for the UK project met with the Bowland team of experts to launch the project for the next academic year. In July 2013, four more project participants were invited to join the IMPULS immersion programme in Japan, with support from Bowland Maths and from the Japanese government.

Since then, the Japanese team have been:

- actively developing Bowland style problem solving lessons for Japan;
- making experimental use of some Bowland cases though public demonstration lessons;
- translating some of the Bowland cases for use in Japan;
- developing a web-site called 'Bowland Japan' to promote the use and development of Bowland type teaching materials; this is currently being renewed.

The tradition in the UK of 'real maths' is deep, going back to the '80s with innovative education materials such as the Standards Units, GAIM, etc. Its leading place in the world is underlined by the fact that the same Nottingham team was also selected to work in the US, funded by the Bill and Melinda Gates Foundation. The Japanese need to explore this new area of maths education, in which the UK has world leading expertise, meant that they had a critical interest in the Bowland Lesson Study Project. The Japanese saw this project as a collaborative opportunity not only for establishing good practice for Lesson Study, but also for joint learning in this relatively unexplored area within problem solving.

2. PROJECT OBJECTIVES

The general aim of Bowland Maths is to increase and improve the teaching of maths process skills and to increase pupils' interest in, enthusiasm for, and skills in mathematics. Within this general aim, the specific objectives of this Lesson Study project were:

A. To test out the Lesson Study approach used in Japan in the context of secondary mathematics classrooms in England through the use of Bowland materials
B. To assist in the PD of the teachers and others involved in the project, with an aim to establish a small group of teachers who could then act as 'Bowland ambassadors' to develop 'networks' of interested teachers in Bowland Maths, using the Lesson Study approach
C. To identify, and subsequently to make, improvements to the teacher guidance and lesson plans of the Bowland materials used in the project and to extend any general lessons to other case study materials
D. To build better links between research in mathematics education, initial teacher education (staff and students), teachers in schools and school based consultancy
E. To adapt a Lesson Study approach that could be used to pursue objectives B, C, and D and which could then be rolled out more widely, in a following project

3. PROJECT DESIGN

The project was undertaken in nine schools, in two 'geographical clusters' - four schools in the Midlands and five in London (see Annex 1). In each school, two or three teachers were directly involved. The schools were selected to ensure that they satisfied two essential conditions:

- The senior management team in the school were supportive of the project.
- There was at least one teacher in the mathematics department experienced in the use of Bowland materials and enthusiastic about taking part in the project.

Each participating school was designed to be supported by at least one external expert, with some involvement from academics in universities. The specific arrangements with the external experts, particularly with respect to the involvement of HE, were designed to be different for the two clusters, and with further variations across schools within the London cluster from the outset. In the Midlands Cluster, core project team members, who were academic maths experts from Nottingham University worked directly with the schools, but it is clear that this kind of direct involvement of research academics is unlikely to be replicable.

In London, in contrast, the configuration of external experts was carefully selected so that it was scalable and fitted the contextual reality of English schools, reflecting the changing roles of schools and related bodies in the England. It was designed to be realistic geographically, and was built on existing human networks and working relationships. The cluster involved two local authority consultants each with multiple schools; another link was with Brunel University involving both ITE and research-oriented academic staff. The role of the cluster leader was to coordinate and to address key issues as they emerged; she deliberately remained 'hands off' with respect to lesson planning, though she participated in research lessons as a 'knowledgeable other' on the day.

Each of the nine schools had three Lesson Study events in the academic year of 2012-13, one in each term (see Annex 4). Each event had four Lesson Study components as below:

- **Lesson planning**. The project teachers in each school formed a team, together with at least one external advisor, to plan a Research Lesson jointly (clarifying/establishing the objective of their research lesson, exploring available materials, known approaches, anticipating student responses, and developing strategies to cope with anticipated responses etc.). The lesson plans for the Research Lesson were shared with the observers in advance of the lesson itself.
- **Pre-lesson discussion**. The external advisor who worked as a team member 'chaired' a briefing session before the research lesson, not only to clarify the focus of their research and to provide background information about the school/class, but also to clarify the roles of observers during the research lesson. This was an area which was different from Japanese practice, as they do not have such pre-lesson discussions in Japan.
- **Research lesson delivery and observation**. One team member then delivered the planned lesson, observed by the other members of the team – and often with other project members and visitors participating as observers.
- **Post-lesson discussion**. A comprehensive post-lesson discussion was held straight after the research lesson on the same day to discuss the experience of the research lesson. The discussion was typically chaired by the external advisor who was part of the team; another external observer played the role of 'Koshi'/commentator and provided, mainly at the end of the discussion, an external commentary of what had been observed during the research lesson.

The overall project, and the activities within the clusters, benefited from advice from the Japanese IMPULS colleagues through their active participation in the project, with three teams (3-5 members – see Annex 5) of experts visiting for a week each, observing research lessons in schools across clusters; there were also considerable email exchanges. In autumn 2013, two short visits from Japan were added to support three schools which decided to conduct lesson study events without any project funding – the first step towards sustainability. Overall, Japanese experts joined 15 out of the 30 research lessons conducted under the project.

Since one of the objectives of the project was to explore the format of lesson study that best suited British circumstances and culture, there was no attempt to prescribe a firm format at the beginning

of the project, either in terms of the roles or planning. Additional flexibility was built into the design in that the two clusters represented different ways in which external advisors participated in school-based lesson study. The Guidelines in Annex 7 are an attempt to capture what was learnt from this project for Lesson Study practice in Bowland maths type teaching in England.

4. PROJECT IMPLEMENTATION

4.1 Key features

The Bowland Lesson Study Project developed its own model of lesson study, which is more faithful to best practice in Japan than many other replication efforts, albeit with some key innovations. The following four features would seem to be the critical aspects of the model.

The role of outside experts - '*knowledgeable others*' Although the literature recognizes the critical importance of such external experts (Lewis et al., 2006), it has been difficult to engage them in practice outside Japan (Burghes and Robinson 2010). For this reason, ensuring the involvement of external experts was central to the project design from the outset. The project was fortunate in that Bowland experts – representing both practitioners and academics – were centrally involved in the project design from the start. Not only did they themselves serve as active knowledgeable others, but they were also proactive in ensuring the participation of other 'experts'. The Japanese colleagues were also helpful in modelling as 'knowledgeable others'. The role of *Koshi* – the external final commentator at the post-lesson discussion – is a critical one which can raise the quality of professional development of the teachers. During the project, a handful of experts developed a good sense of how such a role can be performed, partly through learning by doing, and partly through observing Japanese colleagues perform that role in some of the research lessons. Several others (teachers and experts) also became experienced enough to serve as *Koshi* in the future.

Emphasis on the role of teaching materials (*kyozai*) One key element of the Japanese Lesson Study is the awareness of the need to improve the design of teaching materials to enrich student learning, a feature often overlooked outside Japan (Watanabe et al, 2008, Doig et al 2011). In this project, Bowland Maths provided a well-tested set of teaching materials as a starting point, with discussions naturally extending to cover how their impact could be further enhanced.

Research focus The need to ensure a focus on the objectives of the individual research lessons became clearer over time. Lesson Study is about a specific enquiry that teachers themselves want to address; it is critical that the objectives of the research are clear. Teams developed progressively detailed lesson plans to meet their objectives, anticipating student responses, and planning teacher intervention to enhance student learning. Towards the end of the project, some teams were exploring and selecting teaching materials on the basis of their research objectives. The project initially introduced pre-lesson discussions primarily to inform participating teachers and experts how to observe in classrooms. Over time, pre-lesson discussions became effective forums for introducing not only the background, but also the objectives and key questions to be addressed by the research.

Focusing on Neriage '*Neriage*'– orchestrated classroom interactions to enhance specific learning by students - is considered central for student learning in Japan. As became clear, there is no established wisdom about how to do Neriage for process skills or for open-ended problems, so project teams spent time exploring how best to do it.

4.2 Involving external experts

Initially, the London cluster was designed to have two types of arrangements, one in which a school worked with experts from an ITE department and an academic department from Brunel University, the other in which the schools worked with their respective local government advisors with an additional university expert from Kings College, London joining for the lesson observation and taking the role of koshi.

The arrangements of 'external experts' further evolved during project implementation in the London cluster, because (a) one of the two local authorities drastically changed the role of one of the London advisors; and (b) one of the two higher education academic experts dropped out. The LA consultant was replaced by an independent advisor, who had experience leading LA maths consultants in the London Region, and the cluster leader took over the role of HE expert. These changes enabled the project to see in action the reality of the context for maths education in the UK: advisory relationships change rapidly with the changing roles of local government and schools; further, the role of higher education, particularly that of research academics, in maths education in England is much less 'hands on' than in Japan, where academic education experts are expected to be active in advising on teaching in specific schools.

In Nottingham, the arrangements were simpler and stable throughout the year: three university based experts worked as a team, usually one taking the lead role in working closely with a given school, with others joining in the research lesson observation and pre- and post-lesson discussions.

4.3 Implementation process

In March 2012, an invitation was sent out to all schools with which Bowland Maths had had direct contact, along with all schools of education with ITE roles in England (see Annex 2). Many expressions of interest were received; those that appeared most 'committed' were invited to participate in the project, within the limitations of the agreed funding.

In July 2012, a one-day workshop for all schools was organised to launch the project. The participating teachers and advisors were informed of the project objectives and design as well as being provided with an overview of what Lesson Study is, and what they were expected to do. Subsequently, literature about Lesson Study was made available to all the participants through shared folders on the web.

In London, a further plenary planning meeting was held in early September to discuss timing, roles and functions, and then individual teams of advisors and teachers conducted lesson planning. Throughout the project, advisors discussed approaches amongst themselves and with the cluster leader. The normal mode of lesson planning was for an advisor to visit the school to work with teachers, spending up to a day on lesson planning together, with additional iteration for comments and discussions.

In the Midlands, a lesson planning format was provided by the university experts, which schools then used to plan their lessons collaboratively for the first term, with the university experts only stepping in at the final stage to provide comments. At the start of the Spring and Summer terms, plenary sessions were organized at the University of Nottingham to provide more structured guidance to lesson planning, incorporating lessons learned from the previous term.

All the research lessons were open to all participating teachers, subject to limitations on classroom size. However, most teachers found it difficult to find the time to participate in lessons outside their own schools.

In each term, a group of Japanese experts joined four research lessons – two in London and two in the Midlands; they held a plenary meeting with cluster leaders, some of the other advisors and the leading teachers. These plenary meetings provided the backbone structure to 'collective' reflection across clusters and sharing of experiences.

Four more people were selected by Bowland Maths to participate in the IMPULS immersion programme in Japan in July 2013, for which Bowland maths provided the airfares and IMPULS covered the costs of training and the stay in Japan.

5. OUTCOMES / OUTPUTS

5.1 Testing the Lesson Study approach

Lesson Study was enthusiastically embraced as a valuable approach for professional development by all the responding teachers, with 75% of them giving the highest rating. Their enthusiasm is reflected in the fact that, at the end of the project, seven of the nine participating schools were developing specific plans to continue some form of Lesson Study beyond the project, even without further funding for teacher cover (see Annex 3). One teaching school plans to undertake collaborative lesson study with 10 other 'alliance schools' in the maths of problem solving, with three 'public research lessons' to be jointly developed for 2013-14. The first such 'demonstration' research lesson was conducted to showcase the Lesson Study approach to the collaborative schools in November 2013; the first planning meeting was held in December 2013. In two other participating schools, the maths departments' enthusiasm was endorsed by school level decisions to undertake Lesson Study across subjects. One of these schools conducted a public research lesson in October 2013; in the other school, two multidisciplinary teams of teachers were established school-wide to conduct Lesson Study, and several research lessons have been conducted already. Two other schools are actively planning to extend Lesson Study to the rest of the maths department, one with continued involvement of an external advisor. Another teaching school was exploring a model for sustaining Lesson Study within the department. Even the teachers in the two remaining schools, which do not have definite plans to continue with LS, considered that some form of continuation of Lesson Study in the future to be 'likely'.

The enthusiasm did not stop there. Two of the lead teachers, who moved to new schools in September 2013 are hopeful that they can introduce Lesson Study into their new schools, believing firmly that LS represents the most effective approach for professional development. Teachers and heads of departments from several other schools who observed the research lessons during the project are also eager to try. 'Knowledgeable others' are as enthusiastic. The University of Nottingham has already succeeded in securing additional funding from the Nuffield Foundation to develop sustainable models for Lesson Study, and two of London's advisors have applied for additional funding independently to pursue the continuation of Lesson Study.

What are the reasons for such enthusiasm? The simple answer is the heartfelt conviction by participants that 'this is right and it works'. Most participating teachers found 'collaborative planning' with peer teachers within their own school a powerful experience, which helped them communicate and collaborate better as professionals with each other. One head of department, who came to observe the final research lesson in a participating school remarked that the project team was so enthusiastic and 'raving' about the experience that he had to come to observe what was going on, and that what he saw on the day was so promising that he wants to experiment further. In another department, in spite of the fact that only three teachers were actively involved in the project, their engagement and enthusiasm caught on and the rest of the department staff started using Bowland materials without being told about them explicitly. Another teacher found Lesson Study's focus on student learning refreshing, as he believed that it should be at the heart of teaching, and yet is rarely discussed amongst teachers. One lead teacher, whose head of department became so enthusiastic

that she helped persuade the head teacher to push forward with a school wide experimentation of Lesson Study, described her experience;

> *"I don't think there has ever been a time when the department has worked so closely before. It has never been like this. It was an amazing experience*."

Second, the timing was also right in focussing on problem solving and key processes. Under the new curriculum, there is renewed interest in this area, which, in the words of one curriculum expert:

> "*Teaching of mathematical processes is the weakest area, the one most in need of development and the one we know least about*."

In addition, there may have been a certain 'hype' around the project arising from the direct involvement of university professors, proactive advisors and especially from visiting Japanese maths experts, including those working directly with the Japanese Ministry of Education; all these points have helped create a positive mood amongst school leaders. Is there 'substance' behind this? This is a critical question, as the initial enthusiasm could wane rapidly unless there are 'concrete benefits'. As the aforementioned head of department was quick to add, for them to continue beyond experimentation, there has to be sufficient impact either in terms of continued professional development of existing staff or for training new teachers such that the department can become an attractive place for good teachers to stay.

5.2 Professional development outcomes

The teachers' enthusiasm directly reflected the fact that they found Bowland Lesson Study a valuable professional development opportunity. Indeed, the project was valued as one of the most significant CPD experiences by almost all the teachers who were individually approached for feedback (60% of all participating teachers). These included eight of the nine leading teachers, arguably the 'self-selected' enthusiasts who are more likely to have experienced a wide range of CPD than the average teacher. One lead teacher expressed her view as follows:

> *"I am very grateful to have been a part of this amazing project and I know it has changed the way I think about teaching in far more ways than I am able to express. It has had more impact on me than all my previous CPD combined."*

The project was also seen as unusually rich professional development by many of the 'expert advisors' – including the two cluster leaders. They not only 'learned' something themselves professionally, but also considered LS to be the most effective format for PD for teachers.

Why did they think it was such an effective CPD instrument? Most of them felt strongly that good professional development activities should inform what they do in classrooms; abstract discussions outside classrooms were simply not good enough. Teachers valued the fact that Lesson Study provided specific and subject specific feedback to their classroom teaching. They also found that what they learned was not simply specific to the research lesson they had planned, but also had an impact on improving other lessons more generally.

What was it that they learned? Survey results and interviews indicate that there were at least three types of 'outcomes' that teachers valued.

First, they learned to communicate and collaborate more effectively with each other. The experience of planning lessons together at a level of depth never experienced before, led them to trust each other, not to see each other as 'critics' or 'evaluators' but as allies for better teaching. They learned to communicate as professionals with each other. The consequence of such a change could be significant: in one department, the head of maths, as well as the participating teachers, strongly believed that emphasis in problem solving in the past several years and Lesson Study in the past year have been critical in turning around the department's performance. One

maths education lecturer from a nearby university, who has been observing the department for the last 10 years (partly through his students joining the department as teachers, but also as a governor of the school) agreed that the department has gone through a remarkable change:

> *"I have not seen (any tool other than Lesson Study) that has elevated the quality of discussion in maths departmental meetings. Do not underestimate the power of this tool in getting teachers investing time in talking about the teaching of mathematics… The spinoff into normal maths lessons here has been fantastic… I highly recommend the approach."*

The lead teacher who was at the heart of this departmental transformation explained that Lesson Study helps to build a base for collaborative work amongst teachers so that they can work towards a common goal of better student learning. Lesson Study helps to make 'teaching' a joint enterprise for teachers.

Second, they learned to focus on student learning. One head of department observed that:

> *"The teachers who have been fully engaged with the project are now approaching the planning of lessons from a different angle. There is clear evidence that they are spending more time thinking about the student learning and how their actions within a lesson will promote this. This is now done through focusing more on questioning prior to the lesson and planning opportunities for group work and for discussion."*

They have learned to 'observe student learning' through observations in research lessons, where the focus is to observe in great detail how students respond in classrooms. One head of department exclaimed that although she had professionally observed many lessons before, the 'normal observation' tended to focus on what the teacher(s) were doing. She had never sat with students to observe what they were writing/saying in response to what teachers said. Some teachers were clear that they learned to question students better. Whereas their previous inclination was to lead students to answers by giving clues, now they try really hard to ask questions designed to make students think – a critical aspect of learning about problem solving.

Third, they learned about problem solving and process skills, with teachers learning different things at different levels of progression. Some experienced teachers felt that they developed deeper understanding about what are process skills (e.g. what communication or representation truly is). Others thought that they now had a clearer picture of 'progression' when students learn process skills. For less experienced teachers, Lesson Study provided good opportunities to develop their confidence to use problem solving in classrooms – something which is not easy to do.

In addition, one of the more surprising outcomes was that many 'advisors' also thought that they had learned something. What were they learning? Academic researchers were learning about problem solving – and how complicated it is for students to learn and how little we understand. Advisors were going through deeper thinking about how to help teachers become reflective about student learning. They were also all learning about the fascinating practice of the Japanese Lesson Study and the wealth of knowledge that the Japanese had in observing how to help students learn better. One of the cluster leaders articulated the power of lesson study as its ability to:

> *"bring the analytical rigour of academic research straight into the classroom.*"

The fact that university experts as well as the teaching advisors were 'learning' meant that every event was a rich one in which *all participants* felt professionally engaged – with each getting better in making their own contribution. 'Problem solving' is a unique area in need of far better research and practice – and so a highly relevant area for Lesson Study. In the words of one advisor:

> *"It has made me think much more deeply about how to help teachers reflect on pedagogical subject knowledge. Teaching is deeply complex and requires constant decision-making. The Lesson Study approach helps to make overt some of the decisions, as does the anticipation of students' responses."*

5.3 The use of Bowland Maths materials and its impact on students

The level of knowledge amongst teachers about Bowland Maths materials improved significantly during the project, both amongst the 'experienced' Bowland users as well as for the novices; they became familiar with many more materials than before, and most are now using them more frequently - except for the heaviest users, whose use had appeared to level off to a steady rate. The teachers believed that Bowland Maths materials have a wide range of impacts not only in motivating and engaging students, but in teaching maths content as well as process skills, making pupils more confident, collaborative and capable of evaluating their own work. 95% of teachers thought, and most advisors agreed, that Bowland Maths materials work for all ability sets, although some 'tweaking' and 'scaffolding' is often needed to meet students' specific learning needs.

All the participating schools have increased or plan to increase the emphasis they give to Bowland Maths and similar teaching materials, often reflected in their scheme of work (see Annex 3). One school is making a bold effort to increase the level of problem solving to once every other week – up to 20 such lessons in a year for the four years from Years 7-10. Another which had incorporated assessment tasks at a rate of 1-2 every half term, is now moving to including Bowland Case Studies and other similar open ended tasks as 'projects' every term, starting with Year 7. Indeed, advisors and teachers agree that the regular use of such materials is desirable. One lesson every two to three weeks had the largest amount of support, with some of them explicitly stating the value of including project work every term.

Emerging from among the project participants are some teachers with skills and passion to demonstrate how Bowland materials could be used for the general benefit of UK students, and how teachers could learn to deliver such lessons. The Japanese experts believed that some of these teachers are now 'ready' to give demonstration classes more publically – not only to show Lesson Study methods, but also to show the power of Bowland Maths materials. Indeed, they thought that it would actually make sense to start an effective Lesson Study maths community with the use of good teaching materials such as Bowland Maths; one of them is considering doing exactly that in the US.

The project helped teachers to understand what Bowland Maths materials can do and how they can be used more effectively to enhance student learning. Today there is a much greater array of mathematical problems available as teaching resources than when Bowland Maths started. Within this emerging set of rich problems, the Bowland materials are still unique in the sense that they provide reliable, open and context-rich resources that are fun for pupils, bundled with helpful teacher resources such as lesson plans and student progression grids and with sample student responses. In particular, Bowland cases remain important and unusual in that they can help students learn not only what maths to use and when, but also why maths matters. One lead teacher explained:

> *"It places mathematics and mathematical skills in a real life context – often, (students ask) 'why do you need this, miss?'; 'why is this ever going to help us, miss?'. It (the Bowland material) puts them in real life situations, it gives them ideas of jobs – maths in real life."*

In the words of another teacher, Bowland maths:

> *"taken the ideas of innovative problem solving a step further than before by putting in videos and all the other extra resources that really motivate students and really engage them, and make them forget that they are doing maths. They (students) are doing all this work and accumulating all these skills, without realising that what they are doing is mathematically based. When they do suddenly realize that they are doing mathematical things – they say 'oh, that's why we do maths, and that's its purpose"... I am very passionate about making sure that the pupils realise and understand that maths is not just from the textbook, it's real life, it's out there, and it's how the world works. And Bowland has been able come up with*

resources that show them 'oh, that's where I would use maths, and that is where it happens, that is the purpose of doing things like this!'. As a result, the students are a lot more engaged, a lot more willing to try out new things. As a result, they are much more on the ball not only in Bowland lessons, but in other maths lessons too. They are far more willing to try different forms of mathematical learning because 'now they buy into it'."

Another teacher described that his students, when they realise that maths is relevant and useful, began to trust that the teacher was teaching useful things. They become more attentive to all that is taught – because they believe what they are taught matters in life.

The Japanese experts continued to express their appreciation of the relevance of Bowland Maths materials for Japanese students. According to a senior advisor on maths education from the Ministry of Education, students in Japan are 'switched off' from maths for three reasons – they cannot understand it, the lesson is not interesting (because it does not engage their active thinking), and they can't see the 'point' in learning it. He could see that Bowland Materials addresses two of the three problems:

"In Japan, maths at junior or senior high schools becomes progressively abstract and students cannot see how it can be used in the real world. It is important that students apply maths knowledge and skills to solve problems, and Bowland Maths is particularly effective in making students realise how maths can be useful. I am sure that if students face such problems they would be able to apply their maths knowledge and skills in real contexts."

Experienced users of Bowland Maths were aware of the increasing availability of innovative teaching materials for problem solving. Nonetheless, Bowland Assessment Tasks remains one of the most reliable sources of good teaching materials for process skills that come equipped with resources such as progression grids and sample student responses. Many thought that Bowland case studies remain unique in their richness of context, their engaging presentation and the complexity of some of the problems. However, as more problem solving teaching materials are now available, teachers are looking for good usability and it is important that the accessibility and usability of the Bowland materials are enhanced. Many participants, including the heaviest users, pointed out that 'case studies' are not easy to select and are uneven in their usability, given their very complexity. At the minimum, the Bowland cases and assessment tasks could be more clearly labelled so that their mathematical content is clearer and presented in ways that are related directly to the new curriculum (see Annex 6 for more details).

5.4 Bringing external expertise to classrooms

One aspect of the project most appreciated by all teachers was the contribution of the external experts - both the academics and the non-academic advisors; 100% of responding teachers rated them as valuable and 75% reported them as being very valuable. Even the most experienced teachers found such external expertise valuable, as they were pushed to take risks, to trust students more, and to ask different kinds of questions. Teachers also saw these external advisors helpful in creating a good discipline and support for developing detailed lesson plans, particularly during the early days when they were unclear about how Lesson Study worked.

Contributions from different types of experts. The project experience suggests that different types of experts make different contributions to Lesson Study, which can be complementary to each other. For instance, one Japanese expert saw a 'substantial difference' emerging between the two clusters in the course of the year. While there was not a lot of difference in the lesson plans of November, by February, he saw more explicit research focus in lesson plans, with a clearer emphasis on process skills, and much more rigorous anticipation of student responses. By June, in spite of good progress having been made in the London cluster, he thought that the Midland schools appeared to have gone further; he was clear in attributing that difference to the more active role of

the academics from Nottingham. The Japanese experts were also learning more about how to teach key processes from the research lessons in the Midlands.

Comments from the Japanese experts, as well as from project participants from both clusters, suggest that there may have been three distinct roles that the Nottingham academics played which were not played by other advisors. First, they pushed much more rigorously for the research focus and objective and repeatedly asked teachers to articulate focussed questions (in much the same way that academics would push students writing a dissertation) and to select teaching materials based on that. In the course of the year, all Midlands schools developed a greater focus in their research lessons, and were more selective of the tasks, given such objectives.

Second, during the lesson planning, the Nottingham academics probed more rigorously about the teachers' understanding of the process skills and what it meant to see progress in learning in them. This is not surprising, given that their central involvement was precisely because of their expertise in that. Teachers in the Midlands cluster were clearer about how much better they now understand key processes, in contrast to those from London who typically emphasized the collaborative planning and other aspects of their experience.

Third, the Nottingham experts had expertise as educational designers, which is actually unusual for academic experts. They were much more particular about the problem design and any alternations to teaching materials and asked more questions about how such changes could influence student responses.

None of these three 'skilled contributions' could be routinely expected from maths education advisors or from ITE teaching staff. The Midlands experience was uniquely 'rich' in creating learning for all parties, and was only possible given that (a) the research interest of the Nottingham academics matched squarely with the aims of the research lessons – where they are global leaders; and (b) they are also very strong in teaching material design.

On the other hand, it also became clear that it was essential for the post lesson discussions to end with pragmatic and high-level conclusions about what can be learned from the research lesson; the role of 'Koshi' or the 'summary commentator' was critical for that. Some of the 'academic' discussions during post-lesson discussion tended to lead to more questions than solutions, and some teachers saw them as too abstract and not sufficiently helpful in providing practical insight. In these instances, it was the practitioner advisors and experienced teachers (rather than the academics) who tended to provide better practical insight and ways forward. For 'public' lesson study events with larger numbers of visitors, the role of commentator was particularly important, as their contribution could materially influence visitors' perception about the value of the Lesson Study event as a whole. As most of visitors were teachers, it was essential that such commentary included practitioner insight and realistic suggestions about classroom practices.

The expertise that ITE teaching staff brought from universities is again different, although there will be significant variation between individuals. Two ITE staff who were 'involved' in the project – one from Brunel University and the other from the University of Nottingham, are already taking the first steps in introducing Lesson Study into their ITE. Another member of ITE staff from Birmingham City University commented that he could work with his former students to create a powerful Lesson Study community of practice. Yet another from Canterbury Christ Church University, who visited one of the Lesson Studies, is planning to use Lesson Study in their ITE.

Issues in securing external experts. This project experience showed that it is not easy to secure contributions from external experts. To get **research-oriented academics** from higher education to become engaged in Lesson Study proved to be particularly difficult. One of the initial six academics dropped out of the project in the course of the year, and another is expressing no further interest to continue; it was simply not possible to keep them sufficiently engaged in the project as it was not

directly connected to their personal research interest and they were not flexible enough to adjust. The remaining four academics comprised three from the University of Nottingham, all of whom had research interests focussed on problem solving and professional development in secondary maths, and the leader of ITE at Brunel University, who had been a local authority consultant. Indeed, the academic researchers from Nottingham speculated that they could continue to do something similar whether funded by the project or not – as long as the subject of research lessons remained pertinent to their research interest. The decisive factor in involving research oriented academics appears to be the match between the topics of the research lessons (eg the teaching of problem solving) and their own research interest.

Whether **ITE staff** can free up sufficient of their time to work with Lesson Study appears to depend on specific circumstances. During the project, all the experts except one local authority consultant had to be compensated for their time from the project funds. During Autumn 2013, when the project funding ended, some schools as well as the staff from the University of Nottingham continued to do some work on lesson study without further compensation, but one ITE staff member needed compensation to make significant commitments of their time. Others who expressed future interest to participate in lesson study appeared to have more flexibility in the use of their time.

The roles and institutional base of **practice-oriented experts** – such as consultants and advisors from private companies or local government, as well as not-for-profit institutions – are changing rapidly in the UK. In the emerging 'market' for professional advice, it is increasingly unlikely that such experts could invest significant amounts of their own time in Lesson Study unless their participation was compensated and/or Lesson Study was seen as a way forward for their own organisation.

Experienced teachers represent another source of 'external experts' for Lesson Study. In the course of this project, half a dozen teachers became experienced in providing excellent comments in post-lesson discussions and would certainly be ready to 'lead' lesson planning teams without external advisors; some of them could even start to operate as *Koshi*. The biggest issue about this group of potential experts is that they have little control over the use of their own time. Their schools typically need to be compensated for freeing up their time, but even that may not be sufficient to release experienced teachers to work with other schools. However, it would make good sense for schools to view such activities as 'professional development' for such experienced teachers, which would in turn bring benefit back to the school.

5.5 Lesson Study format

This project has been successful in developing a 'format' of Lesson Study that works well for UK maths teachers. Collaborative planning appeared significantly to reduce the barrier of most potential concern: that teachers may be fearful of 'classroom observation' as being 'evaluative.' The quality of lesson planning improved greatly during the year, with the Japanese experts expressing surprise about how much progress had been made in all the schools – and comparing this favourably with the slower progress made in the USA! Significant progress was made on the need to focus and clarify lesson objectives, to select the right educational materials and resources, to anticipate student responses realistically and to build teacher responses to guide students.

Pre-lesson discussions, which were an innovation of this project, were helpful in clarifying the intended objectives of classroom observation, particularly to participants who were new to Lesson Study, by emphasizing 'observation of student learning' rather than 'evaluating teachers'. Comments from participants indicated that shorter and more focused discussions would have served the purpose in this respect. Many of the points covered in the in the pre-lesson discussions may have been superfluous, such as detailed discussions about individual student capacity or detail about the lesson plan, which could skew lesson delivery as well as observation.

On the research lesson itself, the main fear had been that students would find observers disruptive. The project found that, except for one class in which students appeared to freeze, most lessons took place without any apparent adverse reactions from students. In the class in which the students 'froze', it was clear that they felt 'stifled' by the fact that the 'recording' could record what they were saying in the class.

Much change and progress was made in the format of post-lesson discussions in the course of the year, leading to a better understanding about how best to conduct the roles of the chair and of the expert commentator (Koshi). The chair's tasks are to focus the discussions on critical areas and to ensure sufficient 'discussions' take place on key pertinent points – and especially on student learning rather than on teacher performance. The role of Koshi is to give a final commentary – not a summary of what was said in the discussion, but an expert commentary of what lessons can be learned from the experience.

Based on this project, a Guide has been prepared for professional development for problem solving and the use of Lesson Study with Bowland materials; this is referred to as Annex 7 below, but is available separately.

5.6 Feedback from 'non-project' observers

In the course of the project, groups of outside visitors joined some of the research lessons as 'non-project' observers – often through informal invitations by participating teachers. In autumn 2013, the project supported three more public research lessons to which a wider audience was invited. One was an event, officially advertised as a public research lesson, at which about 30 people participated as observers. The other two were private sessions with specifically invited visitors.

These non-project observers included teachers, maths education advisors and professionals from a variety of organizations, as well as academics and teaching staff from universities. Their responses to the sessions were generally positive, particularly with respect to the value of Lesson Study for the professional development of teachers; this is captured by comments from one observer who attended two of the recent research lessons:

> *"I was left thinking that, if conducted correctly, this approach of collaborative planning and review, coupled with stimulus from outside of the school has the potential to improve teaching and learning significantly."*

The comments of these observers have also been helpful in identifying key issues. For instance, early in the project, several observers questioned the value of the post-lesson discussions, wondering if it was too expensive and unnecessary to have so many people giving feedback to the research team, and whether teachers were too defensive. Since then, the project made significant improvements in structuring post-lesson discussions, so that they were better focussed, with clearer learning points for all participants – visitors as well as the planning team. Such progress was recognized by participating teachers who saw the improvement in the course of the year, and also by one of the non-project observers who had been critical of the earlier event.

The feedback continues to define the future agenda. One prominent academic in maths education, who observed the public research lesson in October, questioned whether the UK has enough people who could serve as *Koshi* effectively, as observed during that day. This is indeed a key issue for the future sustainability of Lesson Study – as discussed below in the final section.

Another maths advisor commented that the public research lesson could be arranged better to allow more active participation by visitors. Designing Lesson Study events so that they are more accessible and valuable for larger numbers of people is certainly a challenge, but one for which this project experience does offer some insight.

6. LESSONS FOR THE FUTURE

The Bowland Lesson Study Project has taken a big step forward in Lesson Study in England for secondary mathematics problem solving. This could be further developed to become a powerful tool for professional development with communities of practice, straddling teachers and experts alike. The enthusiastic reactions from our participants suggest that it offers something special which is largely missing in the system today: an opportunity to work together with colleagues focussing on student learning, an opportunity to observe students and to be observed in classrooms purely for professional development purposes without fear of sanction, and an opportunity to hear comments from external experts on classroom practices.

The various efforts being made by participating schools to continue with Lesson Study show how it has certainly captured their imagination. Most of the participating schools are willing to give Lesson Study a go on their own, but are (rightly) fearful that, without good external inputs, the value of Lesson Study may not be enough to warrant the time commitments and investments required. Lesson Study can be conducted internally amongst teachers, but this project confirms the value of external experts to the exercise.

There are three different types of 'experts' who could be mobilized: research oriented academics, who can help develop better knowledge about professional practice; ITE teaching staff who can create new generations of teachers for whom Lesson Study could become standard professional development practice; and practice-oriented experts and advisors, including experienced teachers, who could generate practical ideas about improving classroom practice. The conclusion is that it is important to engage all three types – as they play different roles within the English system.

The experience in the project confirmed that problem solving represents an area of maths education which requires far better knowledge and understanding. As one of the teachers remarked: "even the university professors are not clear about process skills!" Whereas there is sufficient research evidence to inform how to teach most mathematical concepts, the same is not true for problem solving. Further, the definitions of key processes are still evolving, and will probably continue to do so as further research takes place.

Indeed, the fact that problem solving is not yet a well established teaching practice is an excellent reason why a 'dense form of Lesson Study', involving research active academics from universities is critically important. Lesson Study not only enables teachers to learn, but also provides opportunities for researchers to get a better insight into this critical area of professional practice. Research-oriented academics should be able to help turn new insights from classrooms into knowledge that can be shared more widely by the maths education community. Lesson Study could be an ideal instrument to strengthen the generally weak ties between research academics and schools.

Given that pedagogical issues around problem solving have great potential to generate new research and knowledge, it is to be hoped that there will be enough academic researchers who will be interested in contributing to this relatively unexplored area of enquiry. Where there is such a match of interest, and willingness and skill of academics to address practitioners directly, they could be excellent resources to serve as *Koshi* in research lessons; this would also give academics excellent opportunities to influence professional practice and so help develop new ways in which individual academics could be 'connected' to classroom practice – as in Japan.

For sustaining Lesson Study efforts more generally, it will be important to ensure the involvement of 'practice-oriented' experts in their full diversity - experienced teachers, advisors and ITE staff. The national circumstances around advisory and training relationships are changing too rapidly for there to be a single base for such experts. ITE is also changing (eg. through programmes such as Schools Direct and Teach First), with increased roles for teaching schools and the increased

involvement of contracted companies. Any future effort to create Lesson Study communities should include current movers and shakers amongst advisors/consultants, wherever they are. But equally, it makes sense to involve *future* movers and shakers – younger dynamic teachers with a good track record in teaching – who are likely to become tomorrow's leaders.

Time commitments from external experts will need to be secured by professional compensation. University academics may be able to exercise greater flexibility over how they spend their time if the activity 'fits' their research. How to teach problem solving and the use of Lesson Study are certainly intellectually challenging topics and it is hoped that more academics will rise to the challenge and develop them as research interests. However, even for them, additional 'fee' or honoraria could be helpful. In the medium to long term, it makes sense to create a climate in which schools pay for such 'experts'. In the short term, however, it is unrealistic to expect that schools to pay without seeing what they get for their money. It is essential that a group of 'experts' should be actively 'trained' to develop expertise and a track record in conducting Lesson Study, so that they can make 'material contributions' to, and to lead, Lesson Study events in schools. They should also develop experience acting as *Koshi* – to develop the capacity to deliver key insights in Lesson Study, as valued by teachers/schools.

There are three other 'systemic obstacles' to the further development of Lesson Study. First, teachers in England may still see 'lesson observation' as part of performance management. As such, they are likely to be fearful of making their teaching open to wider scrutiny. This project successfully created an environment in which teachers did not feel threatened, although it is possible that this was at least partly helped by the self selection of the participating teachers, who were proactive enough to be interested to try. It may not be easy to extend Lesson Study to other teachers, especially to those who see little need for their own professional development. The minimum requirement would be for the department to have a professional development strategy firmly in place to promote the idea of observing each others' lessons without punitive consequences.

Second, many teachers commented that finding the time to do lesson planning will be a key challenge. In the schools that are planning to continue Lesson Study, there is already school management endorsement for teachers to engage in lesson planning, but whether this extends to relieving teachers of some of their other tasks is not clear. The time issue may be inseparable from the psychological issue that lesson planning at the level of detail required is unusual for teachers. It is not easy to take up a new activity, nor is it easy to invest time without understanding fully the value of it. Again, a departmental strategy to take on board lesson study as a professional development practice would be the most obvious route to encourage effective teacher participation.

Third, on a practical front, there are significant barriers to creating time and space to enable numbers of teachers to participate in observing research lessons. Even if the time spent planning is justified as professional development, it is not easy to find a slot in the crowded teaching schedule where several teachers from the department can participate in lesson observation; this can also cost money for replacement teachers.

There are international examples of 'school systems' that have created solutions for such issues. First, adopting Lesson Study as professional practice at a *system level*, can reduce evaluative pressures and make it common practice across the teaching profession. Second, it is possible to 'create' time slots for research lessons which are less costly to participating schools. In the US, one state which adopted Lesson Study, created a specific day/time for all schools to participate – in a way similar to the district-orchestrated Lesson Studies in Japan, where public research lessons are put on specific days for all teachers to attend. Another method adopted in the US is to put on the research lesson after school hours, by retaining the class outside normal school hours. Many parents like the idea that their children are getting a 'special extra lesson' and teachers find it convenient as there is no scheduling conflict. Another option is to conduct a research lesson during a time earmarked for a departmental meeting, an idea put forward by one of the schools which is

interested in participating in the future. Failing such 'systemic' options, conducting research lessons in the afternoon rather than the morning makes it easier for teachers from other schools to participate, as they can use the 'lunch time' for travel, and limit their absence to half a day.

The experience from this project makes it clear that there would be a major benefit in establishing Lesson Study as a professional practice more widely in England for teachers to learn about practical problems solving in mathematics lessons. What should be the next step? Bowland Maths has played a critical role in creating this unique and rich collaboration with Japanese experts which has made this a 'one-of-a-kind' project. Going forward it is not necessary to restrict problem solving Lesson Study to any one set of teaching materials: teachers should select their own 'research lessons' although they will still need good teaching materials to avoid wasting valuable teacher time. For the project being funded by Nuffield, in addition to continuing with Bowland materials, the plan is to use selected materials from sources such as AMP from Nuffield Foundation[1], MAP[2] from the Universities of Nottingham and California, Berkeley, and from Nrich[3].

There is one further question on 'coverage': how far should the next round of maths Lesson Study efforts extend beyond process skills in 'problem solving'? In this project, there was an emerging 'focus' on teaching problem solving through contrasting different approaches and alternative strategies, which is clearly an area requiring a significant focus through Lesson Study. However, to establish Lesson Study as a professional practice in the English maths context, to limit the focus in this way may not be productive, as most teachers do not yet have sufficient understanding of the need to teach such process skills. A wider focus to include lessons with other types of context rich problems, but designed to teach mathematical concepts (rather than processes), could be useful, as the value of Lesson Study may be easier for teachers to understand in this context. One of the teachers who visited Japan for the IMPULS workshop pointed out that she could see the rationale for anticipating student responses much more clearly in the Japanese lessons – which were to teach concepts; and *Neriage* is easier to see working in simpler problems that teach concepts, precisely because teachers understand student progression far better. There may also be more 'research-oriented academics' who would be interested in participating if the Lesson Study was to teach mathematical concepts - albeit through problem solving. On the other hand, too far a shift into teaching content, even through problem solving, could jeopardise the valuable opportunity to improve the pedagogy of process skills. Further, in purely practical terms, if English Lesson Study merely attempted to replicate what Japan is already doing, it will command less interest from Japanese colleagues and opportunities for further collaboration would be reduced. Perhaps the best compromise would be to focus on problem solving for 'mathematical concepts' and for 'mathematical processes', but not to extend this to routine 'mathematical procedures.'

It is clear that the Bowland Lesson Study Project has initiated another innovation with potential that can push English maths practice to another level. It is extremely fortunate that the Nuffield Foundation, with whom Bowland Maths has had excellent collaborations in the past, is enabling Nottingham University to continue to explore Lesson Study practice for professional development, with an emphasis on finding ways to make it sustainable in the future – without external funds. Perhaps the final, and critical, role for Bowland Maths will be to review its various materials to explore what needs to be done to make them even more usable and so ensure that the emerging Lesson Study community has access to top quality teaching materials that continue to break new ground.

[1] http://www.nuffieldfoundation.org/applying-mathematical-processes
[2] http://map.mathshell.org.uk/materials/index.php
[3] http://nrich.maths.org/frontpage

Annex 1: List of participating schools and advisors

Midlands Cluster: Cluster leader - Malcolm Swan

Name of School	Lead teacher	External Expert / University link
Derby Moor	Dominic Hudson	Professor Malcolm Swan; Geoffrey Wake, Associate Professor; Dr. Colin Foster, Senior Research Fellow – all from the University of Nottingham
Heartlands Academy	Elnaz Jevaheri	as above
Swanwick Hall	Amy Rouse	as above
Redhill	Paul Crossley	as above

London Cluster: Cluster leader - Alice Onion

School	Lead teacher	Primary External Experts	Other External Experts
Hollyfield, Kingston	Nicole Worthey	Sunita Babbar, Brunel University	Dr Dawn Leslie, Brunel University
Ravenswood	Charlotte Mace	Christina Moody, Secondary Maths Consultant, London Borough of Bromley; Eileen Coan, Coanmaths Ltd	Sunita Babbar, Brunel University
Coopers	Alison Brown	as above	as above
Dagenham Park	Jacqueline McLeod	Matt Lewis, Secondary Maths Consultant, London Borough of B&D	Professor Jeremy Hodgen, King's College, London; Dr. Dawn Leslie, Brunel University; Alice Onion, Kings College, London
Robert Clack	Jacqueline Mann	as above	as above

Annex 2: Project Timeline

2012

July	Project launch workshop
September	London: Cluster meeting
November	Four research lessons and a plenary meeting with Japanese experts

2013

Jan	Midlands cluster meeting
February	Four research lessons and a plenary meeting with the Japanese experts
April	Midlands Cluster meeting
June	Four research lessons and a plenary meeting with the Japanese experts

Annex 3: Schools Follow up on (i) Lesson Study; (ii) the use of Bowland Maths Materials

Lesson Study (LS)

- **Heartland Academy** – Head teacher committed to LS to being adopted school-wide. Conducted a public demonstration lesson in October 2013. Seeking collaborating experts from Birmingham City University.
- **Swanwick Hall** – LS experimented school-wide – established two cross subject teams to implement LS with several research lessons already conducted. Seeking collaborating experts from Nottingham University.
- **Redhill** – leading LS effort as part of their teaching school alliance with 10 other schools. The first demonstration research lesson conducted in November 2013, with a planning meeting in December 2013.
- **Robert Clack** – a new project integrating lesson study into the KS3 department with a borough advisor planned for the next year. The borough advisor also exploring collaborative networks with primary schools to build lesson study communities.
- **Hollyfield** – "The department is now more open to collaborative planning for research lesson as part of professional development" and is planning a project for the coming year. The lead teacher has conducted a research lesson with a new team member in November 2013 – with Bowland extra funding support for an external advisor.
- **Coopers** – "The department is now working in teams to plan a series of lessons for next year using the same way of working as the project"
- **Ravens Wood** – 'They are all very eager to try the concept out." Exploring ways 'to make LS process fit for the department.'
- **Dagenham Park** – very likely to continue LS – though unclear content. Started a project week every term, which requires similar coordinated planning
- **Derby Moor** – Likely to continue, though no definite plan

Use of Bowland Maths Materials and Changes in Scheme of Work (SoW)

- **Heartland Academy** – Putting specific Bowland tasks into the scheme of work over summer, 2013.
- **Swanwick Hall** – Scheme of Work already included assessment tasks – at a rate of 1-2 each half term to consolidate concepts learned. Now trying to introduce projects (case studies) – starting with year 7, one hour every week and take as long as it takes them to learn. If that works, will do the same for other years.
- **Redhill** – Already had half a dozen tasks that were written into the SoW. Now rewriting to introduce for Year 7-10 about 20 lessons of problem solving in each year – one every couple of weeks.
- **Robert Clack** – the lead teacher from the project wrote Bowland tasks into the SoW over summer 2013
- **Hollyfield** – "Next year we are going to be using the Bowland lesson materials and model to train all maths staff."
- **Coopers** – 'We now have two groups of teachers developing how we would integrate Bowland in the first three weeks of the term next year for Year 7 and 8. One group will do Kangaroo, the other will do Sundials (covering 9 lessons)'
- **Ravens Wood** – "We have introduced Bowland activities into our schemes of work, so will hopefully trial these tasks on a larger scale this year."
- **Dagenham Park** – As a result of (the Bowland Project), we now implement one project in the last week of every term. At key stage three, we carry out one project per term.
- **Derby Moor** – Bowland tasks and problem solving are explicitly written into the scheme of work for 2013-2014.

Annex 4: List of Bowland Research Lessons

Redhill
- Torbury Festival
- Representing Dance Moves
- Hot Under the Collar
- Hot Under the Collar (extra research lesson after the project)

Derby Moor
- Z Factor
- Outbreak
- Mission Rainforest: Escape

Heartland Academy
- Product Wars
- Day Out
- Taxi Cabs
- 110 years on (extra research lesson after the project)

Swanwick Hall
- Outbreak
- Highway Link Design
- Keeping the Pizza hot

Ravens Wood
- Rainforest
- Astro Zoo
- Alien Invasion

Dagenham Park
- Olympics
- My Music
- Rods and Triangles

Hollyfield
- Magic Sun Puzzle
- 110 years on
- Z factor
- Spinner Bingo (extra research lesson after the project)

Coopers
- Crash Test Dummy
- Torbury Festival
- Mystery Tours

Robert Clack
- How Risky is Life
- Mission Rainforest
- Fruit Pies

Annex 5: List of Visiting Japanese Experts

19th-23rd November 2012

- Toshiakira FUJII, Ph.D. Director of Project IMPULS; Professor, Department of Mathematics Education, Tokyo Gakugei University
- Akihiko TAKAHASHI, Ph.D., Specially Appointed Professor, DePaul University, Chicago, U.S.A
- Keiichi NISHIMURA, Ph.D., Associate Professor, Department of Mathematics Education, Tokyo Gakugei University

11th-15th February 2013

- Keiichi NISHIMURA, Ph.D., Associate Professor, Department of Mathematics Education, Tokyo Gakugei University
- Hiroyuki Shimizu, Maths Advisor, Yamanashi Prefecture
- Chiharu Honda, Maths Teacher, International School affiliated to Gakugai University

10th-14th June 2013

- Akihiko TAKAHASHI, Ph.D., Specially Appointed Professor, DePaul University, Chicago, U.S.A
- Keiichi NISHIMURA, Ph.D., Associate Professor, Department of Mathematics Education, Tokyo Gakugei University
- Atsushi Nagao, Maths Education Advisor, Ministry of Education, Japan
- Tatsuhiko SEINO, PhD., Associate Professor, Yamanashi University
- Sayuri Takada, Researcher, Impuls Project, Gakugei University

21st October 2013

- Akihiko TAKAHASHI, Ph.D., Specially Appointed Professor, DePaul University, Chicago, U.S.A

11-13 November 2013

- Keiichi NISHIMURA, Ph.D., Associate Professor, Department of Mathematics Education, Tokyo Gakugei University

Annex 6: Recommendations for Bowland Maths

The main lessons learned from the project for Bowland Maths materials is that, for the purposes of Lesson Study, especially for teachers trying to develop a concrete understanding of process skills, the assessment tasks provide better entry points than do many of the case studies. This is partly because assessment tasks are simpler and shorter - they were originally designed to require no 'teaching', but also because they come with assessment guides such as progression grids and student responses. The progression grids in particular, which provide illustrations of what progress students can make in process skills, have proved to be an invaluable tool for teachers in developing lesson plans.

In thinking about the future of Bowland Maths materials, two contextual developments are relevant. First, schools as well as teachers are much more aware of the needs to include context rich problem solving, partly because of the new curriculum's emphasis on it, but also because of the increasing use of such problems in exams. Second, more problem solving teaching materials focussed on process skills are now available on the web than when Bowland Maths first started, some with good resources to guide teachers. These include AMP, MAP and Nrich, which collectively form a good set of problem solving materials mainly as pure maths and puzzle-like problems.

Nuffield AMP provides updated versions of process oriented problems, originally developed back in the 1980s by Kings College, London. Since the updates were developed in collaboration with Bowland Maths, they use the same progression grids as in the assessment tasks, one of the key innovations of Bowland Maths. MAP resources were developed by Nottingham University in collaboration with Berkeley University to provide formative assessment problems to match the US curriculum – providing a clear curricular link to US Common Core State Standards. They too used some of Bowland Assessment Tasks for process skills, but also provide teachers' guides which give anticipated issues/problems that students are likely to face and questions/prompts which could be used by teachers to guide the students to address such issues – although they do not provide progression grids. The developments of some others, such as Nrich, offer increasing numbers of (smaller) rich problems which are searchable in terms of the new curriculum requirements and are aimed at developing specific aspects of key processes, such as representing or analysing. In

addition to all the above, the Bowland Maths' professional development modules were used as a base to develop CPD materials for Europe on PRIMAS, and now in the US too.

These developments illustrate both that Bowland Maths is a development within the UK maths education tradition of context-rich problem solving tasks, but also that it has made its own mark by pushing this development further in several distinct directions in the past 5 years or so, providing innovative stepping stones at key junctures. In addition, the best known context rich, open-ended problems are still those provided by the Bowland cases and feedback from teachers (especially the more experienced) shows that they value the 'power' of the Bowland case studies in linking maths to a 'real' context – as they see how they can change student motivation to learn fundamentally – though even these experienced teachers say that the case studies are harder to work with.

The question is what Bowland Maths should now do that others are not doing? What can be done as a 'final effort' in revising Bowland materials that could make a further critical impact in the field? Or is the mission of Bowland Maths, in starting this new direction of maths teaching, now complete?

Feedback from participating teachers and experts indicate that there would be much value in any of the following specific developments:

- **Assessment tasks.** Still the 'easiest place' to look for process skill tasks in terms of content, but there are problems with their 'labels' as they are not easy to 'search' or link with the curriculum
  - **Minimum**
    - Identify links between the tasks and the new curriculum
    - Provide clearer labels for the identification of particular tasks
    - Update those items that have subsequently been used in MAP
  - **Preferred**
    - Add anticipated problems and teacher prompts/questions in ways that are similar to what has been done for MAP
    - Add additional tasks, insofar as there are gaps with respect to the new curriculum
- **Case studies.** Still the pioneer and leader in context-richness which enhances engagement, relevance and open-endedness – although not for all the cases. However, the cases need better usability and easier access. The cases are also very variable in their level of openness and quality, which could lead to dramatically different approaches being taken by teachers.
  - **Minimum**
    - Provide clearer labels and simpler explanations – to guide teacher selection of cases
    - Identify the links between the cases and the new curriculum
    - Revise some tasks in light of the types of problem seen during the LS project
  - **Preferred**
    - Produce more 'focused' lesson plans – to clarify the 'teaching points' of each lesson so that the potential 'takeaway points' for students are clearer. This is because, for many of the more complex tasks, the materials can be used with different objectives – and it is tempting for users to 'tweak' the material in various directions to teach different things. But, for most of the materials, there are specific aspects that form a 'natural focus' for the lessons. For instance, many open-ended problems provide a natural ground for teaching how to model and how to strategize; yet many teachers get distracted and take lesson time to teaching the content maths. The 'natural focus points' of the process skills should be made clear in the teachers' guide, with guidance about how to cope with the content issues
    - Divide some of the cases into lessons that could stand alone, still within the context of the case, but that would provide a lesson of about one hour; as such, they could also be used as a 'lead' to other extensions
- **Professional development modules.** Some participants who were familiar with these pointed out that, while their content is right and what is needed, the entry points to them are too abstract, and teachers have too little time to explore them. The modules are more likely to be used if 'groups' of teachers can be motivated to learn, so that there is an 'external structure' to provide

discipline to individual teachers. Lesson Study provides an ideal setting in which teachers can learn along with the module – though to facilitate this, some modification, particularly in the way they are introduced and labelled, may be needed.

Minimum

- Update the Professional development modules, with clearer labelling so that Lesson Study participants can see that these are pertinent resources

Preferred

- Some of the modules have been updated through PRIMAS. Bowland Maths should make the updated versions available on the Bowland website – so as to facilitate easier access for UK teachers (with appropriate acknowledgement to PRIMAS).

What is the role of lesson study for Bowland Maths in all this? The Lesson Study experience in this project provided valuable insight into what could be improved, but the structure of the project was not right for identifying specific changes to the materials - because the style of Lesson Study encourages teachers to 'change' the materials, so that what is used in the classroom is rarely what needs to be 'trialled'. Rather, Lesson Study will (and did) generate observations about the teaching materials, which may be helpful for revising them – as this project found. It will also generate 'variations', some of which may be an improvement on the original material.

A better way forward for revising specific teaching materials, if there were funding for it, might be to commission a small group comprising an experienced teacher and one or two educational material designers to conduct Lesson Study events with the *explicit* objective of improving the material. This might be done for a small number of the most popular cases and put on a new website on which 'variations' from users could also be posted – on the basis of their own LS, along with reviews. This would be another 'stepping stone' as a final effort for Bowland. If an education publisher could fund (or even participate in) such a venture, it could pave the way for sustainable and continued material development which could go beyond what a 'one-off' charity such as the Bowland Trust can hope to achieve. This could also lead to an arrangement similar to that in Japan where textbook writing academics, publishing companies, and practicing teachers all observe and learn from the large number of Lesson Studies that permeate the system – and then use the results to update materials.

Annex 7: Guide for professional development: Problem solving and the use of Lesson Study with Bowland materials

Available as a separate document

References

Burghes, D. N., D. Robinson, Lesson Study: Enhancing Mathematics Teaching and Learning. CfBT Education Trust 2010

Doig, B., S. Groves. 2011. Japanese Lesson Study: Teacher Professioannld Development through Communities of Inquiry. Mathematics Teacher Education and Development Vol 13.1 77-93

Lewis, C., Perry, R., & Murata, A. (2006). How should research contribute to instructional improvement? The case of lesson study. *Educational Researcher*, *35*(3), 3-14.

Watanabe, T., Takahashi, A., & Yoshida M. (2008). Kyozaikenkyu: A critical step for conducting effective lesson study and beyond. In: F. Arbaugh, P. M. Taylor (eds.), Inquiry into Mathematics Teacher Education, pp. 139-142. San Diego: Assocation of Mathematics Teacher Educators.