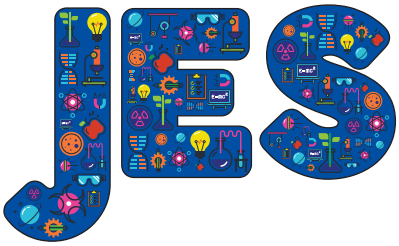
Transforming assessment and teaching practices in science inquiry



Natasha Serret • Christine Harrison • Catarina Correia • Jason Harding

Abstract

ASSISTME (Assessing Inquiry in Science, Technology, and Mathematics Education) is an EU FP7 research project. In collaboration with 8 European countries, this four-year (2013-2017) project aims to find out how to support primary and secondary teachers in the formative assessment of inquiry-based learning in science, technology and mathematics.

Within this context, we developed a professional development programme that aimed to support primary teachers in their teaching and assessment of science inquiry. Our research aims to investigate how teachers transform their teaching of science inquiries and the assessment conversations that they have during classroom inquiries. This paper begins to identify what kinds of professional development experiences enable this transformation to take place.

Our data sources include written teacher reflections, audio-recordings of the professional development meetings and observed lessons and semi-structured post-lesson interviews. We draw from a multi-step, open-coding analysis of selected transcripts of the audio-recordings of classroom talk made during lesson observations. We substantiate this with teacher reflections, arising from the professional development sessions, to extend our understanding of effective ways to guide teachers in transforming their teaching and assessment practices in scientific inquiry.

Our preliminary analysis suggests that transforming the assessment and teaching of science inquiry requires some specific professional development opportunities. Sharing some examples of classroom inquiries that were bounded, initially, and then later open (Wenning, 2005) gave teachers the confidence to incorporate inquiry within their existing practice. This was introduced in conjunction with regular professional reading (Turner et al, 2011) and a focus on discrete inquiry skills (e.g. making predictions).

Collectively, this allowed teachers to sharpen their professional understanding of classroom inquiry. The critical teacher reflections, made during professional development days, supported teachers in refining their formative practice. Their assessment conversations went beyond accepting or rejecting answers and, instead, facilitated a more open and formative discussion that encouraged children to share their ideas with others.

Keywords: Inquiry, assessment, professional development

Introduction

This study forms part of a pan-European EU FP7 project, 'Assessing Inquiry in STEM Education' (ASSISTME), which is researching into classroom assessment practices during inquiry activities. There has been a series of previous projects on inquiry learning across Europe over the last decade, with a view to encouraging classroom pedagogy that supports problem-solving, collaborative learning and greater student agency.

To bring in such changes is always difficult and our hypothesis is that transforming assessment and teaching practices requires seeking ways to support teachers in recognising a need for a transformation to take place. In this paper, we share some of the research that focused on primary science practice in England. This was conducted by the King's team, in collaboration with Enfield Council, and fed into the wider European ASSISTME project. We outline some of the inquiries that were used as a vehicle for creating this teacher need for transformation and the professional development support that was developed alongside this.

We will discuss our findings through the following research question: *What enables primary teachers*

to transform their assessment and teaching practice in science inquiry and what challenges might they face in achieving this?

Background and context

Inquiry-based science education (IBSE) equips learners with a range of attitudes and skills that can support them in school and beyond (Rocard, 2007). Some of the characteristics of inquiry include questioning, reasoning and interpreting (Bernholt, Rönnebeck, Ropohl, Köller & Parchmann, 2013). These skills are often nurtured within the context of real-life, relevant inquiries that necessitate collaborative investigation and discussion. Learning in primary schools tends to focus on encouraging children to share ideas, find answers to questions and generally improve their literacy, oracy and numerical skills and these can be utilised in the IBSE classroom. As a consequence, purposeful primary science inquiry can provide rich opportunities for children to learn and for learners to share evidence of their learning through classroom talk. In these situations, teachers can pick up evidence of how well children are developing their understanding and skills and make decisions about suitable next steps in learning. These potential formative interactions are often spontaneous and transient. They rely on skilful professional ability to create suitable tasks that encourage learners to talk and engage in these formative interactions. In addition, they require a pedagogical expertise that can recognise, assess and respond to specific aspects of inquiry performance. Shalveson *et al* (2008) describe these kinds of in-the-moment assessment conversations as 'interactions on the fly'.

In England, the level of emphasis put on to the learning and teaching of primary science has been influenced by a number of wider, national requirements. These include how primary science is positioned within the National Curriculum (DfE, 2013) and within the formal summative testing requirements at the end of primary schooling in England. This position of primary science has varied considerably over the last twenty years. As a consequence, its status as perceived by teachers, learners, parents and the wider educational community has waxed and waned. This wavering status has had implications for the quality and quantity of science taught in primary schools (Harlen, 2013; Pollard *et al,* 2000), initial primary teacher education and as part of continuing teacher professional development. These wider national circumstances have reduced the opportunities that teachers might take to instigate primary science assessment conversations. Set within this context, the UK ASSISTME research team explored how assessment conversations that take place during a lesson (*interactions on the fly*) can be used to support the learning of primary science inquiry.

For each of the Teacher Meetings, we provided input to allow the teachers to try out inquiry activities that they could adapt for their own classrooms. The overarching aim of this primary science element of the ASSISTME project was to raise teacher confidence in practical science inquiry, encourage the participating teachers to take professional risks and make primary science inquiry a more regular feature of learning. Once underway, we hoped to strengthen and transform a particular aspect of their formative practice, where using science inquiry would open up richer opportunities for teachers and learners to have assessment conversations *(interactions on the fly)* during the lesson. Later professional development could then focus on how to transform assessment practice in order to harness this assessment evidence and enable learners to make progress in science inquiry.

Nine participant primary teachers embarked on a one-year professional development programme. Enfield Council invited schools within their area to participate and, through a process of self-selection, these nine teachers were identified. The professional development involved six half-day sessions that focused on the pedagogy and assessment of science inquiry. Over the course of the year, nine inquiry lessons (see Table 1) were introduced. Resources for the inquiries were set out and the team at Enfield shared these with the teachers in such a way that these participant teachers were put in the position of the learner. This enabled the Enfield team to model the kinds of teacher questions, interactions and responses that can facilitate assessment conversations. Consequently, during professional development sessions, the participant teachers had an opportunity to do the inquiries for themselves, begin to consider how their classes might approach

these inquiries and have professional discussions with the other participant teachers about the types of resources, pedagogy and underlying subject knowledge that might be required for each inquiry. As the professional development year progressed, space was created during these sessions for the teachers to reflect on how they implemented these inquiries in their classroom. The Enfield team focused the professional dialogue around assessment evidence: *'How could you tell that progress was made? What did you notice? What did this tell you?'* These later professional discussions supported the teachers in beginning to recognise what an assessment conversation (*interactions on the fly*) might look like within the context of a primary science inquiry.

Methods

This study follows a qualitative research approach (Cohen, Manion & Morrison, 2011). Our primary data sources draw from written teacher reflections, audio-recordings of lessons and teacher professional development meetings, combined with field notes and semi-structured post-lesson teacher interviews. Over the duration (Sept 2014–July 2015) of the project, data were collected from 6 professional development days and 10 classroom lesson observations. Within these 10 lesson

Table 1: A summary of the UK primary inquiry lessons for ASSISTME 2014-2015.

Inquiry	Summary
Mouldy bread	Children are presented with some samples of mouldy bread. In groups, they use observation, questioning and discussion to describe what they see and develop some explanations for their observations. They are then asked to investigate what conditions will keep bread mould-free for the longest amount of time.
Multi-coloured milk	In groups, children are given some yeast, water and sugar and 3 measuring cylinders. They are set with the task to investigate what is the best way to make yeast rise.
Yeast	Children are given some milk in a saucer. They are asked to observe what happens when several different food colourings are added to the milk and then washing up liquid is added in the middle. The question they are asked is 'What do you think is happening and why?'
Skittles	Children are asked to observe what happens when different coloured 'skittles' sweets are placed separately in a dish of water. How does each colour spread? Do all colours behave in the same way?
Brilliant bubbles	Children are presented with a database of possible suspects in a crime investigation. In groups, children apply their skills of deduction and reasoning to decide who is the most likely suspect and explain how the evidence they have supports this decision.
Criminal intentions	Children are given water, washing up liquid, glycerine and sugar. They are asked to investigate how to make the best bubble (biggest/strongest/lasts the longest). They are encourage to explain their findings, e.g. 'Why does glycerine/sugar help?'
Healthy crisps	In groups, children are given a sample of several different brands of ready salted crisps. In their groups, they have to decide on a method to help them work out which is the healthiest crisp. They need to then share their findings and explanations with the class.
Drinks cooler	Children are given three drinks bottles, filled with room temperature drinking water. One bottle is wrapped up in kitchen paper, one in wet kitchen paper and one with no kitchen paper. Children then take the temperature of the water in the three bottles and then take the bottles outside on a windy day, or leave them in front of a fan for 30 minutes. The temperature of the water is taken again and they are then asked to discuss and try to explain the evidence.
Best biscuit	This combines science inquiry with technology over a series of several lessons. During these lessons, children explore (through dunking different commercially produced biscuits in warm tea), investigate and design a biscuit that they think will be the best one for taste, transportation, cost and ability to be put in a warm cup of tea without breaking up.

observations, four of the teachers were observed twice and two teachers were observed once.

A multi-step analysis was applied to all transcribed lesson data. Our interest was in how the teachers both encouraged children to offer ideas and particularly how they used these interactions to prompt formative action. This might be encouraging children to think more about an idea, or to give more detail in an answer, or to link a response with inquiry ideas that had arisen in another context. Firstly, in order to establish a unit of analysis, research field notes and the audio-recording were used to develop an overview of the lesson. This helped to identify a macro unit of analysis, in which we could select an episode where the classroom dialogue evolves around one main theme (e.g. recap from previous session). The potential for formative assessment was used to help select episodes for a finer level of analysis. In particular, episodes where children seemed to be active and offer ideas were closely examined to explore and describe the formative practices used by the participant teachers during these episodes.

Within each of the episodes, we established the micro unit of analysis, which was typically each participant's speaking turn. An open-coding approach was used to analyse this section of the transcript (Cohen, Manion & Morrison, 2011). We adopted a coding system developed by Ruiz-Primo and Furtak (2007) to analyse the episodes, referred to as ESRU coding in the literature. In this system, each fragment of the dialogue is allocated to its purpose within the interaction. So, the teacher might ask a question to elicit student thinking (E), recognise the student contribution made in response to this (R) and then, using the feedback from the student response (S), make a suggestion to help the student move forward with their thinking (U). Ruiz-Primo and Furtak explored the lesson interactions they observed to seek out complete cycles, where teachers had used the student response to make a judgement and take an action. However, we became aware that several of the episodes that we had selected because of their formative potential actually did not contain many complete ESRU cycles. This concerned us, as we could recognise the formative potential at a macro-level, but the analysis through ESRU coding was not revealing a similar finding. On careful scrutiny of the flow of the interactions, we became conscious of several clarification attempts by the teacher within the discussion, where it seemed that the teacher was probing student ideas and encouraging other students to comment on ideas before a decision was made to take formative action. In other words, the interactions were a series of negotiation about a specific idea between the teacher and the learners aimed at developing a reciprocity of understanding.

This led our team to develop a further layer of analysis of the classroom interactions that utilised the assessment framework suggested by Torrance and Pryor (2001), to enable us to identify the teacher intention underpinning sequences of teacher speaking turns. The main advantage of our new coding system is that we could differentiate between divergent and convergent assessment approaches. Divergence occurs when teachers ask questions or make statements that instigate further thinking about the ideas being discussed, thus opening up the ideas for further consideration. For example, a teacher may ask, *'How might this evidence be used to help us answer our inquiry question?'* or *'How confident are we that we would get similar results if we repeated this inquiry tomorrow?'.* Convergence happens when teachers expertly lead learners to make links with pre-determined and usually previously-met lines of thought, closes down further discussion and establishes the idea as accepted practice. In this type of interaction, a teacher might ask, *'So did we expect the mould to grow more in the warm conditions on the radiator?'* or *'Does our conclusion give a reason as well as an answer to our inquiry question?'.*

Analysis

Analysis is still being finalised and the example below illustrates how the ESRU coding system is helping us to characterise the formative practice that is arising during these inquiry lessons. In a whole class discussion, the teacher encourages different groups to share how they went about their science inquiry to investigate which is the healthiest crisp. Individual students share what evidence they drew from and how they analysed this and used it to answer their inquiry question. The teacher probes (U) their thinking further by encouraging students to consider their results and apply their findings in different contexts (e.g. with a diabetic):

Teacher	**Did you have anything different? How did you sort your information out, did you do quite similar to them, where you did a chart?**	R, E
Student	First of all we did, we based (all of it on that ? 0:56:27) on that and then Miss told us to do this.	S
Teacher	**Okay.**	R
Student	So basically, so it had the least sugar, the sugar is probably the least healthy category, it had the least salt, it weighed the most, no, actually it weighed second most and it had third most calories, meaning overall, then the sugar and the salt were the main bits, having a few more calories than Pop, it made it better because those two (categories ? 0:57:20), weighing 100 more than Pop and that and Hula Hoops, didn't matter, 'cause it still really was the best.	S
Teacher	**The best, what if you were diabetic though, would that influence what you thought would be healthier?**	R, U
Student	Yeah.	S
Teacher	**So, if I was a diabetic, which I hope I'm not, not yet anyway, which one would suit me the best, from the information you've got there, if I was a diabetic, which crisps should I buy?**	U
Student	The Pops.	S
Teacher	**The Pops, they've got the least sugar.**	R, U
Student	Is it the one with the least sugar?	S
Student	Oh, that was [inaudible 0:57:57] Hula Hoops.	S
Teacher	**It's my favourite, Hula Hoops, I'm safe with that option, okay, what about if I've got what I do have, high blood pressure, which one should I avoid?**	R, U
Student	With less salt.	S
Teacher	**I need the least salt.**	R
Student	The least salt is...	S
Teacher	**What would you advise?**	E
Student	Mighty Lights.	S
Teacher	**Mighty Lights, but I don't like Mighty Lights.**	R, U
Student	Then don't eat crisps.	S

In terms of the ESRU coding, there are three complete cycles, but when you read the transcript and look for developing ideas and formative action being taken, it is not until the end of the 60-minute lesson. The key point in this interaction is when the teacher makes a judgement on what has been said so far and questions that by asking:

'The best, what if you were diabetic though, would that influence what you thought would be healthier?'

This question encouraged the student to rethink how they had explained their reasoning of the 'best' crisp and to redefine this in relation to the special case (i.e. the diabetic) that the teacher had suggested. So, this is an example of a divergent assessment approach, which not only challenged the child who was speaking, but also engaged the rest of the class in thinking about their results.

Conclusion

Ongoing analysis of episodes of classroom talk within the primary science inquiries begins to help us to characterise the formative practice that arises during the assessment conversations *(interactions on the fly)*. An initial analysis of teacher reflections, as evidenced during professional development discussions, teacher writing and in their post-lesson interviews, suggests that dealing with ideas as they arise in the inquiry classroom can be challenging for teachers, as they attempt to transform their assessment and teaching practice. Within the context of science inquiry, these teachers need to learn how to walk a tightrope between finding a balance of promoting learner autonomy (asking probing and not leading questions), while supporting and enabling purposeful inquiry learning. For some teachers, this balance was influenced by their subject knowledge confidence, available time and their ability to allow inquiries to take different paths. The following reflection made by one of our experienced participant teachers, having taught primary for 33 years, highlights this: *'…I think I have got used to new things not working… I have got this picture in my mind of how things should be and what I would really like them all to do. It never happens…this has helped me overcome that fear of failure…doing these activities because I don't know a lot of the technical vocabulary or the science side of things as well…'* (Enfield teacher reflection, Primary PD, 13.5.15).

The findings from this research project so far indicate that transforming assessment practice requires creating opportunities for inquiry learning to take place and consequently a genuine need for formative interaction to support and enable progress. The following professional learning experiences can support primary teachers with this process:

- **Introduction of bounded and open-ended inquiries** (Wenning, 2005). Our primary project teachers found the use of closed (bounded) inquiries motivated them to start transforming their practice at the start. These inquiries gave them the structure, support and confidence to embrace science inquiry and promote this within the classroom. Towards the end of the professional development year, these teachers were introduced to more open-ended inquiries at a point when these teachers were willing to adapt and contextualise these to meet the particular needs of their class.

- **Focus on discrete inquiry skill-enabling richer and diagnostic formative interactions**. Drawing attention to a particular inquiry skill (for this project, making predictions/drawing conclusions), and creating time and space (14 weeks per skill) for learners to become familiar with this skill, secured both a teacher and learner grasp of discrete inquiry skills. When these discrete skills were unpicked, through success criteria, they also became a means of communicating with teachers and learners what successful classroom inquiry looks like.

- **Teacher engagement with professional literature**. Additional professional support was provided through the use of a teaching resource, *It's Not Fair,* (Turner, Keogh, Naylor & Lawrence, 2011). Set reading and written reflection tasks were set over the course of the professional development days and enabled the participating teachers to consider the effectiveness of the questions they used during the inquiries, their expectations of the learning arising from the inquiries, their interpretations of this and how this collectively is informing their professional understanding of the nature of science inquiry.

- **Critical self-reflection on practice and impact on learning**. A significant proportion of time and thought was dedicated to enabling teachers to

articulate their reflections on their assessment practice. These discussions were triggered by a sharing of the teaching and learning inquiry classroom experiences that took place in between professional development sessions. Through careful and expert facilitation, these reflections became the vehicle for teachers to consider how their assessment and teaching practices have been transformed. This forced an opportunity for teachers to make their subconscious formative practice explicit.

Providing teachers with inquiries and structuring these around discrete skills created opportunities for learners to reveal their understanding of science. For our primary project teachers, this emphasised the need to provide formative feedback and to develop a better ability to recognise when they were providing purposeful formative feedback and when they were not. A key implication for future research, pre-service and continuing professional development, will be to consider how to share and use examples of assessment conversations to best support teachers in refining their formative practice.

References

Berntholt, S., Rönnebeck, S., Ropohl, M., Köller, O.& Parchmann, I. (2013) *Report on current state of the art in formative and summative assessment in IBE in STM* – Part 1. Kiel

Cohen, L., Manion, L. & Morrison, K. (2013) *Research Methods in Education*. 7th edition. Taylor and Francis

Department for Education (DfE) (2013) *Science programmes of study: key stages 1 and 2. National Curriculum in England.* London: DfE

Harlen, W. (2013). *Assessment & Inquiry-Based Science Education: Issues in Policy and Practice.* Italy: Global Network of Science Academies (IAP) Science Education Programme (SEP)

Harrison, C. (2006) 'Banishing the quiet classroom', *Education Review,* **19,** (2), 67–77

Pollard, A., Triggs, P., Broadfoot, P., Mcness, E. & Osborn, M. (2000) *What pupils say: changing policy and practice in primary education*. London: Continuum

Rocard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henriksson, H. & Hemmo, V. (2007) *Science Education NOW: A renewed pedagogy for the future of Europe, Brussels: European Commission*. Technical Report No. EUR22845

Ruiz-Primo, M.A. & Furtak, E.M (2007) 'Exploring teachers' informal formative assessment practices and students' understanding in the context of scientific inquiry', *Journal of Research in Science Teaching,* **44,** (1), 57–84

Shavelson, R.L., Young, D.B., Ayala, C.C., Brandon, P.R., Furtak, E.M., Ruiz-Primo, M.A., Tomita, M.K. & Yin, Y. (2008) 'On the impact of curriculum-embedded formative assessment on learning: a collaboration between curriculum and assessment developers', *Applied Measurement in Education,* (21), 295–314

Torrance, H. & Pryor, J. (2001) 'Developing formative assessment in the classroom: using action research to explore and modify theory', *British Educational Research Journal,* **27,** (5), 615–631

Turner, J., Keogh, B., Naylor, S. & Lawrence, L. (2011) *It's Not Fair – or is it?* Sandbach: Millgate House Publishers and Hatfield: Association for Science Education

Wenning, C.J. (2005) 'Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes', *Journal of Physics Teacher Education Online*, **2,** (3), 3–11

Dr. Natasha Serret, Dr. Christine Harrison and **Dr. Catarina Correia,** King's College, London, and **Jason Harding,** Enfield Council.