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Assessment of Inquiry Skills in the SAILS Project

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ABSTRACT: Inquiry provides both the impetus and experience that helps students acquire problem solving and lifelong learning skills. Teachers on the Strategies for Assessment of Inquiry Learning in Science Project (SAILS) strengthened their inquiry pedagogy, through focusing on seeking assessment evidence for formative action. This paper reports on both the successes and dilemmas that taking this approach led to as 16 science teachers attempted to assess inquiry skills in high school classrooms.

KEY WORDS: inquiry, assessment, formative

BACKGROUND

Over recent years, there have been several European Union Framework 7 projects (EUFP7), such as S-TEAM, ESTABLISH, Fibonacci, PRIMAS and Pathway, whose remit has been to support groups of teachers across Europe in bringing about the radical change in pedagogy suggested in the Rocard Report (2007). This report recommended that school science teaching should move from a deductive to an inquiry approach, These EUFP7 projects have been successful in highlighting the importance of Inquiry-based Science Education (IBSE) across Europe. Inquiry-based science education (IBSE) has proved its efficacy at both primary and secondary levels in increasing children's and students' interest and attainments levels while at the same time stimulating teacher motivation. They also have allowed us to determine the range of understanding of what the term inquiry means to teachers, and to establish to what extent skills developed through inquiry practices have been identified. One area that has remained problematic for teachers and cited as one of the areas limiting the development of IBSE within schools has been assessment. The literature on teacher change suggests that teacher change is a slow and often difficult process and none more so than when the initiative requires teachers to review and change their assessment practices (Harrison, 2009). This EUFP7 project Strategies for Assessment of Inquiry Learning in Science (SAILS) aims to prepare science teachers, not only to be able to teach science through inquiry, but also to be confident

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and competent in the assessment of their students' learning through inquiry.

Inquiry skills are what learners use to make sense of the world around them. These skills are important both to create citizens that can make sense of the science in the world they live in so that they make informed decisions and also to develop scientific reasoning for those undertaking future scientific careers or careers that require the logical approach that science encourages. An inquiry approach not only helps youngsters develop a set of skills such as critical thinking that they may find useful in a variety of contexts, it can also help them develop their conceptual understanding of science inquiry based science education (IBSE) and encourages students motivation and engagement with science.

The term inquiry has figured prominently in science education, yet it refers to at least three distinct categories of activities—**what scientists do** (e.g., conducting investigations using scientific methods), **how students learn** (e.g., actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists), and a **pedagogical approach that teachers employ** (e.g., designing or using curricula that allow for extended investigations) (Minner, 2009). However, whether it is the scientist, student, or teacher who is doing or supporting inquiry, the act itself has some core components.

Part of the reason for this slow implementation of IBSE in science classrooms is the time lag that happens between introducing ideas and the training of teachers at both in-service and pre-service level. While this situation should improve over the next few years because of the EUFP7 Inquiry projects, there is a fundamental problem with an IBSE approach and this lies with assessment. While the many EUFP7 Inquiry projects have produced teaching and training materials, they have not produced support materials to help teachers with the assessment of this approach. Linked to this is the low level of IBSE type items in national and international assessments which gives the message to teachers that IBSE is not considered important in terms of skills in science education. It is clear that there is a need to produce an assessment model and support materials to help teachers assess IBSE learning in their classrooms if this approach is to be further developed and sustained in classrooms across Europe.

The Strategies for Assessment of Inquiry Skills in Science Project (SAILS) consists of 14 partners from across Europe and is currently in its second year of development. The prime aim of this project is to produce and trial assessment models and materials that will help teachers assess inquiry skills in the classroom. At the centre of this work is Assessment for Learning. The King's College London team consists of Chris Harrison, Brian Matthews and Paul Black and these researchers have been working with a pilot group of 16 expert science teachers developing the first round of materials for the project. The materials produced are then being trialled in 13 different countries to see how the approach fits within different cultural contexts.

ASSESSMENT OF INQUIRY SKILLS

Inquiry based science education is an approach to teaching and learning science that is conducted through the process of raising questions and seeking answers. An inquiry approach fits within a constructivist paradigm in that it requires the learner to take note of new ideas and contexts and question how these fit with their existing understanding. It is not about the teacher delivering a curriculum of knowledge to the learner but rather about the learner building an understanding through guidance and challenge from their teacher and from their peers.

Some of the key characteristics of inquiry based learning are:

- Students are engaged with a difficult problem or situation that is open-ended to such a degree that a variety of solutions or responses are conceivable.
- Students have control over the direction of the inquiry and the methods or approaches that are taken.
- Students draw upon their existing knowledge and they identify what their learning needs are.
- The different tasks stimulate curiosity in the students, which encourages them to continue to search for new data or evidence.
- The students are responsible for the analysis of the evidence and also for presenting evidence in an appropriate manner which defends their solution to the initial problem (Kahn & O'Rourke, 2005).

In our view, these inquiry skills are developed and experienced through working collaboratively with others and so communication, teamwork, and peer support are vital components of inquiry classrooms.

Within an inquiry culture there is also a clear belief that student learning outcomes are especially valued. One characteristic of inquiry learning is that students are fully involved in the active learning process. Students who are making observations, collecting data, analysing data, synthesizing information, and drawing conclusions are developing problem-solving skills. These skills fully incorporate the basic and integrated science process skills necessary in scientific inquiry. In England, there has been a move to support more practical work in science classrooms, through the Get Practical Project (Abrahams et al, 2012). This project resulted in observable changes in the emphasis given to practical work in schools and also to improvements in the learning of science concepts. They also found that teachers needed to plan scaffolding (Wood et al, 1996) in order for their learners to be guided towards viewing scientific phenomena in a similar way to what their teachers perceive it (Ogborn et al, 1996; Lunetta, 1998). Such an approach requires the teachers to take note of what their learners struggle with and then plan and implement teaching that helps their pupils improve. In other words the approach that teachers need to take is formative.

A second characteristic of inquiry learning is that students develop the lifelong skills critical to thinking creatively, as they learn how to solve problems using logic and reasoning. These skills are essential for drawing sound conclusions from experimental findings. While many projects have focused on the evaluation of conceptual understanding of science principles developed, there is a clear need to evaluate other key learning outcomes, such as process and other self-directed learning skills, with the aim to foster the development of interest, social competencies and openness for inquiry so as to prepare students for lifelong learning. This has been the aim of many of the EUFP7 projects so far and central to this approach is teamwork and collaborative behaviour. So the move to implement more IBSE type learning across Europe has been successful in terms of raising awareness of the importance of this approach but the introduction of these ideas into mainstream teaching and learning has been less readily taken up.

In many schools, we know that generally science practicals are presented as recipes to follow so that students experience scientific phenomena (Abrahams & Millar 2008) This approach means that the raising of questions about phenomena lies with the teacher rather than the student. So, in most science practicals, the student role is limited to simply collecting and presenting data that is then made sense of by the teacher. This approach to practical work is unlikely to aid conceptual understanding and development of inquiry skills beyond practice of a limited number of skills.

Three topics have been selected for the first set of materials – Food, Rates of Reaction and Speed and Acceleration. The project also developed a small number of stand-alone inquiry activities where the emphasis was on developing and assessing specific inquiry skills to help the teachers focus on assessing the inquiry skills without needing to focus, from an assessment perspective, on the developing conceptual knowledge at the same time.

Essentially the project teachers approached the assessment of inquiry skills as an on-going process that fitted alongside the activity. A helpful way of understanding the dynamics of the classroom, and the constraints and possibilities it offers for dialogue and feedback, is through Perrenoud's (1998) concept of the regulation of learning. He describes two different types of classroom – the 'traditional' and the 'discursive or negotiated' classroom. In traditional classrooms, lessons are highly regulated with activities tightly defined and, consequently, learning is prescribed. The outcomes tend to be content driven and predetermined, with little opportunity for the students to play an active role in their own learning. From these types of lessons, teachers can only glean what students cannot do, according to the narrowly defined terms of reference (Marshall and Wiliam, 2006).

In a discursive, or negotiated, classroom, the tasks are more open-ended. The scope for students to be active in their learning, and to govern their own thinking, is greater. This creates a classroom environment in which teachers can more readily gauge understanding and provide meaningful feedback for learners. Learners co-construct knowledge through such learning experiences, and the teacher's role is both instigatory and facilitatory. A starting point in this process is formulating questions that make students think and which motivate them to want to discuss ideas. For example, questions such as, 'Is it always true that green organisms photosynthesize?' are better at generating talk than, 'Which types of organisms photosynthesize?' Better still would be if the learners begin to raise questions as then both the responsibility for the direction of learning as well as the co-construction of knowledge lies with the learners.

The teachers made decisions about which of the inquiry activities they would pilot in their classrooms and, at each of the teacher meetings, they reported on how the inquiry activity had gone and how easy or difficult it was to assess the inquiry skills of the learners as they did the activities. Field notes were taken at each meeting by two of the researchers and provided the main data source for reporting on the progress of the project.

FINDINGS

The SAILS pilot so far looks promising. The SAILS pilot teachers reported that they gave far more curriculum time to inquiry than they had anticipated was possible at the start of the project. After each meeting teachers were asked to try, as a minimum, one inquiry project of around an hour. All 16 teachers did considerably more than this with several teachers doing extended inquiry projects over several weeks and the majority trying 3-6 inquiries with classes between January and June. As the teachers gained more confidence with the IBSE approach, the inquiry activities became more open in their structure and direction and several of the teachers reported that this more open approach not only further motivated learners, it allowed the teachers to assess the learners on a wider range of inquiry skills. Certainly in the first few inquiry activities teachers focused on aspects of planning or of data collection whereas in the later inquiry activities teachers felt more confident to also assess broad-reaching skills such as critical thinking, teamwork and communication. This not only broadened the range of skills being assessed but encouraged the teachers to think about how they might organize the assessment process to capitalize on the assessment data collection of their learners, while at the same time, setting feasible goals in terms of the amount of data they could collect as learning was taking place. The teachers comments from the teacher meetings highlights this aspect:

> "*Clearly they have always worked in groups but you start to see who works well in a group and who doesn't when they do this (inquiry). Before I'd have just ticked a box for everyone but now I can see there's a range and have started to understand how to support those individuals who find working in a team difficult."* (Teacher 7, Meeting 3)

> " *Teamwork is getting better and they are starting to take this seriously now they know I am looking for this. They tell each other if someone is taking over or if they rush ahead without considering what others might say. The don't reach a consensus but they do stop and think a bit more and they sort of see it helps."* (Teacher 4, Meeting 3)

> " *It was shambolic at first but they are getting the hang of it (teamwork). I am starting to too 'cos I can now see more clearly what they need to demonstrate to show this*." (Teacher 9, Meeting 3)

The project teachers reported that they feel that they gain far more evidence of student performance by collecting evidence during the inquiry activities than from marking reports of the inquiry. They have realized that only a limited number of skills can be assessed if the evidence is only sourced from the written report and many of the interchanges they witnessed as students discussed which inquiry questions were likely ones to form the inquiry and then how to identify, select and control and manipulate variables were much richer in reality than in the written reports of the investigation, because, by then, the ideas been through so way iterative interchanges by the time the final investigation was reported, that the data had been reduced to stark statements. While the written reports indicated whether the students could or could not identify relevant variables, the ease with which they could do this and their competence in justifying one variable as testable and rejecting another was far better portrayed during the inquiry than in their reports. Teachers also recognized that as well as getting a better feel for their students' capabilities, there were some areas that were better assessed during the inquiry than could be done by other assessment methods and they discussed the limitations of the previous system of assessing inquiry by coursework and also those of the current system for assessing inquiry by controlled assessments.

> "*When we did Sc1 investigations you just got out your mark scheme and did a P,O,A,E. It was quite easy matching up what they had written with the criteria but I now realize how limiting that was. You weren't really testing investigative skills but just seeing if the pupils had managed to follow a set way in presenting things.*" (Teacher 15, Meeting 2)

> "*I thought assessing during the inquiry was going to be much harder than it's turned out to be. It's quite easy to see who is on track and who missing the point completely and talking to them confirms your assessment while providing the opportunity to do something about it.*" (Teacher 9, Meeting 3)

Observing learners in the classroom as they carry out investigations, listening to learners piece together evidence in a group discussion, reading through answers to homework questions and watching learners respond to what is being offered as possible solutions to problems all provide plentiful and rich assessment data for teachers. Since the formative use of the assessment data is essential to drive the pedagogy most likely to bring about conceptual change in the learners, our approach has been first to strengthen the formative assessment that occurs within inquiry teaching. So the project teachers have focused on recognising and collecting the assessment data that arises directly from inquiry lessons. To do this they need to think carefully about the variety of ways in which learners might respond to the new ideas or new contexts or challenging question being offered.

Assessing while the inquiry was underway rather than relying solely on the evidence in the written work, that the students produced, was a novel experience for the teachers. By listening carefully to classroom discussions during inquiry or to solutions to problems that have arisen during the inquiry or to group reflections on an inquiry activity, teachers can gather evidence of their learners' emerging understanding. Teachers can note misconceptions, identify partly answered questions from full answers, and recognize errors and possible reasons why such errors are occurring. Such data is rich in inquiry lessons because the very nature of the approach means that the lesson is challenging and so understanding is interrogated through the actual performance of the inquiry.

Through a formative approach, the teachers were able to find out which inquiry skills students can do well and which they had problems with. They were then able to use this assessment data to scaffold the next stage in learning for their students. What this meant was that inquiry skills that occur late in the scientific process, such as critiquing method were not limited by the planning or doing phase. In fact, because the inquiries were more open than the teachers and students had done previously, there was greater variation in the methods and this allowed some of the students to critique in a more focused way as making errors in the planning and doing stage led to greater opportunity to critique the inquiry approach. A further factor that proved extremely useful was that, because more inquiry activities were attempted, the teacher could witness how their students utilized their inquiry skills in a range of context. The teachers reported two consequences of this. First they felt more confident that the student could demonstrate a particular skill and hadn't just got lucky in their choices in the various stages of the inquiry as the quote below illustrates.

> "*You're more sure you have got the assessment right for each student because some inquiry activities are more straightforward than others. You sort of come away thinking that they would be able to do this skill or that skill whatever bit of science we choose to look at*." (Teacher 2, Meeting 4)

Secondly, the teachers began to get a 'feel' for the range of difficulty between the various inquiry activities and started to form a better understanding of quality and progression both in a holistic sense and for individual inquiry skills through seeing the same classes attempting five to eight inquiry activities over a period of about six months.

> "*We started off with the floating one because we thought the kids would enjoy it. While it was a great one for them raising questions and for looking at proof and disproof, it was clear that almost all of them needed to do some work on their observations. So we did the biscuit mining one even though initially we had discounted that one because it didn't look at the outset as open as the other ones. ……Gradually we found an order emerged as each activity offered a range of skills at differing degrees of complexity and that was when we realized where the gaps were skill-wise and so we worked out what we needed to look at in the final one, which led to the Ink Splot activity*." (Teacher 6, Meeting 4)

Such data place teachers in a good position to sum up the progress and to have a realistic awareness of each learner's skill set and understanding of inquiry by the end of the learning sequence of activities.

The teachers were also are able to feed evidence back into their teaching and so respond formatively to both the needs and progress of learners. The teachers also reported that they had begun to see the inquiry capabilities of their learners more positively then they had done when previously doing practical work with these youngsters. The teachers were surprised by how well the learners managed to raise inquiry questions, how innovative the learners could be when not limited to following a particular path to solving in inquiry problem and how learners were willing to learn from their mistakes while still remaining motivated.

This type of assessment has high validity. It satisfies one of the conditions for validity in having high reliability, in that the learner is assessed on several different occasions, thereby compensating for variations in a learner's performance from day to day, and in several ways, thereby sampling the full range of learning aims. The fact that the learner has been assessed in contexts which have been interspersed with the learning secures both coverage and authenticity, particularly because the teacher is able to test and re-test her interpretations of what the data means in relation to each individual's developing understanding. Such data place teachers in a good position to sum up the progress and to have a realistic awareness of each learner's understanding by the end of the sequence of inquiry activities. This is radically different from assessing the learner in the artificial context of the formal test, and it is far more valid i.e. the teacher can be far more confident in reporting – to a parent, or to the next teacher of the learner, or to any others who might want to have and use assessment results – about the learner's achievement and potential.

However, engaging in more inquiry in their classrooms and assessing in this different way also caused concerns and dilemmas for the SAILS pilot teachers. These were:

- Teachers unable to collect data on every student during each inquiry activity and some teachers worried that this could affect the reliability of their results
- Teachers working formatively and so unsure on what they should report - student's first attempt, last attempt, average attempt?
- Students working collaboratively and this may affect individual performance because their interaction with others may have given them tips and hints and so an individual may have been able to perform a particular skill at a higher level than they would have done working with different peers

These concerns are shadowed by continual concerns by many of the SAILS pilot teachers on public and government confidence in teacher assessment and how the teachers might communicate to parents and others why and how a more formative approach can be as robust as the assessment judgments that are made through examinations at the end of courses.

CONCLUSION

Work so far on the SAILS project has indicated that teachers are willing to strengthen their commitments to IBSE through taking a formative assessment approach to inquiry. The SAILS pilot teachers have demonstrated that they are able to assess as the inquiry learning is taking place and then use this assessment data to inform later stages in the IBSE learning. The formative approach to assessment of inquiry in science classrooms has encouraged teachers to allow students to do more IBSE type work than previously and to take a more open approach to inquiry and this has enabled the students to be more innovative in their inquiry approach. In turn, because the students are expressing a broader range of skills than the science teachers normally observe in general practical work, the teacher shave reported that they have been surprise and pleased by student's inquiry capabilities and willingness to learn from making mistakes.

Issues relating to public confidence in teacher assessment remained problematic and we hope to address that issue in the coming year through looking at how science teachers in our partner countries across Europe work with these ideas. This will be also hopefully strengthened by helping the SAILS pilot teachers in England address how they might build an assessment portrait of their learners' work in inquiry over the course of the school year. While the project has a considerable way to go in creating a working assessment system for inquiry, we feel that our pilot teachers have made large advances in taking these ideas forward. It has been through the hard work, perseverance and trust that our project teachers have developed as a community of practice that has driven and sustained this move forwards and we look forward to the next stage as these ideas are advanced by the UK pilot teachers and tested by other teachers across Europe.

For more information on the SAILS project – see www.sails-project.eu

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