

Report from the FP7 project:

Assess Inquiry in Science, Technology and Mathematics Education



ASSISTME

Teacher Guidelines

Christine Harrison, Catarina F. Correia, Natasha Serret, Paul Black

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Lead participant	King's College London
Contact person	Christine Harrison
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Key message 1 Inquiry-based pedagogy is an effective vehicle to develop competencies that prepare future citizens to engage with scientific and technological issues and to make informed decisions about their own and society's future.

Key message 2 Inquiry-based pedagogy enhances student and teacher motivation and engagement with science. Research based evidence shows that inquiry based pedagogy is correlated with increased students' academic achievement.

Key message 3 Teachers need to be made clear of what inquiry-based pedagogy looks like in a classroom. This includes a clear understanding of the features of this approach, and how these differ from other forms of teaching and learning.

Key message 4 Teachers need to be made clear of classroom assessment purposes and processes in the context of inquiry. This includes recognition and design of suitable assessment tasks which can be used for formative and/or summative purposes.

Key message 5 ASSISTME explores the use of four distinct classroom assessment strategies. These were interactions on-the-fly, structured assessment dialogue, teacher written-feedback, and peer written-feedback. These strategies provide different opportunities to gather evidence of learning, interpret, and use it for formative and/or summative purposes. They all have a place in classroom assessment and can be integrated in different parts of the learning cycle.

Key message 6 Formative use of evidence of learning and learning itself are intertwined and should not be separated from one another. Having a clear understanding of the lesson learning aims and of how they fit within a broader learning picture is very important to guide effective formative action.

Key message 7 ASSISTME identifies a need for professional development that supports teacher understanding of formative assessment and inquiry-based teaching. The professional development should create opportunities for the establishment of a vital community of practitioners who can share good practice and their critical reflections of their practice.

Key message 8 Teachers need to be given time and opportunities for professional development. This is best approached through trialling and developing inquiry learning and assessment as a long term intervention through sharing experiences with other teachers, teacher educators, and researchers.

Key message 9 Classroom materials and assessment tools need to be made available, so that teachers can be supported in adopting and developing their own resources.

Key message 10 Our findings highlight the challenges teachers faced in adopting this practice. It requires a change in teaching philosophy for many teachers. Initially, this means putting in more time and effort into planning and resourcing. Teachers also go on to share the positive impact on their practice and their learners.

Why is inquiry-based pedagogy important?

Inquiry competencies are what learners use to make sense of the world around them. Inquiry competencies (e.g. Investigation, Argumentation, Problem Solving, Design, Innovation) capture a complex set of skills (e.g. raising questions, making observations, evaluating evidence).

An inquiry approach helps motivate young people to learn science and develop critical thinking and scientific, mathematical and technological reasoning. These factors are important in preparing citizens that can make sense of the world they live in, that can understand the changes that science and technology will bring to their lives and make informed decisions about their own and society's future. Inquiry-based learning has proved its efficacy at both primary and secondary levels in increasing children's and students' interest and attainment levels in STEM subjects, while at the same time stimulating teacher motivation (Minner, Levy, & Century, 2010)¹.

Key message 1 Inquiry-based pedagogy is an effective vehicle to develop competencies that prepare future citizens to engage with scientific and technological issues and to make informed decisions about their own and society's future.

Key message 2 Inquiry-based pedagogy enhances student and teacher motivation and engagement with science. Research based evidence shows that inquiry based pedagogy is correlated with increased students' academic achievement.

What are the main features of inquiry-based pedagogy?

Inquiry-based pedagogy creates learning environments where the teacher and students engage in a process of asking questions and seeking answers. High quality inquiry-based lessons are characterised by:

- Students' active engagement with challenging and open-ended problems/situations that have multiple solutions/responses.
- Students have control over the direction of the inquiry by choosing and developing their own investigation methods.
- Students draw on prior knowledge to design and conduct an investigation, and interpret their findings.
- Students communicate their solution to the inquiry question in an evidence-based way.
- And throughout this process, students identify their learning needs and use multiple resources (e.g. their peers, teacher, and the web) to fill in the gap. Inquiry lessons are typically highly interactive and driven by frequent teacher-student and student-student dialogue.

The opportunities for learning that arise from inquiry activities depend on the type of inquiry activity that is chosen, and on how it is planned and enacted in the classroom. Inquiry activities can be led by the teacher and/or by the student.

¹ Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of research in science teaching*, 47(4), 474-496.

- Guided inquiry is teacher-led, and is characterised by the teacher identifying the problem to be researched and giving students extensive practical orientation (e.g. deciding what investigation method will be used).
- Free-inquiry is student-led, and is characterized by students identifying the problem to be researched and developing their own experimental design.

Given the way the inquiry activities tend to be planned and enacted, guided inquiry is often associated to close-ended questions and/or procedures, while free inquiry tends to be more open-ended. As students move from guided to free inquiries, teachers create more opportunities for students to articulate their thinking and expose their alternative conceptions. From the teacher's perspective, inquiry lessons can provide a rich-bed of evidence of students' understanding, which in turn empowers them to decide on possible routes to support student learning. From the students' perspective, inquiry lessons provide opportunities to develop collaborative learning skills, autonomy and self-regulation. Inquiry-based lessons create opportunities for students to engage with authentic scientific practices and real-life contexts.

Inquiry-based pedagogy has an important role to play in science, technology, and mathematics (STM) learning. However, inquiry-based pedagogy is not the only way to teach and learn STM, and it should be used alongside other pedagogical approaches. As an example, inquiry-based science lessons provide an opportunity for learning science, and learning about science, while simultaneously acquiring a wide variety of transferable competencies that support learning in general. The acquisition of science knowledge should not be dissociated from the development of inquiry competencies, because they support each other. As an example, inquiry competencies such as formulating hypothesis and evidence-based conclusions heavily rely on understanding multiple scientific concepts.

Key message 3 Teachers need to be made clear of what inquiry-based pedagogy looks like in a classroom. This includes a clear understanding of the features of this approach, and how these differ from other forms of teaching and learning.

Why do we need to focus on assessment in inquiry-based pedagogy?

It is important that we assess the knowledge and competencies that we value. Current assessment systems in STM subjects often focus on content knowledge rather than competencies. Summative assessments often capture only some aspects on inquiry performance such as presentation and interpretation of data and do not focus on higher order reasoning skills like raising testable questions, synthesising ideas and critical evaluation. This is partly because assessment of such skills is difficult to accomplish with written test questions and within the time frames of an examination. Assessment of the higher level cognitive skills required for inquiry are better collected from classroom assessment scenarios, which are both more authentic and interactive environments that link better with the ways in which the subject concepts were learnt.

How can classroom assessment support inquiry learning?

Assessment is the servant of teaching and learning. In the inquiry classroom, teachers can monitor how students respond in novel situations and can question and challenge the reasons learners have for making specific choices or interpretations.

Probing students' understanding helps teachers and learners focus on the progress that students are making and realise what instruction or practice is needed to bring about further improvement.

Classroom assessment provides both the time frames and opportunities to look at how learning through inquiry is developing. Classroom assessments are the processes of collecting evidence of performance that can be used for formative or summative purposes. Formative assessment encompasses a range of teaching and learning interactions that capture and inform the learner and the teacher of the progress that is taking place as learning occurs. These interactions enable the learners to communicate their thinking and also provide an opportunity for the teacher (or peers) to give feedback. Such feedback is often both evaluative and informative. Most importantly, feedback should support the learners in understanding where they are at in their learning, where they need to go next, and how to get there. Formative assessment is, above all, a way of conceptualising the advancement of learning on a day-to-day basis through responsive teaching practices.

The formative use of classroom assessment information can be broken down into four components: eliciting evidence of learning from learners, interpreting this evidence (deciding where the learner is in her learning journey against a set of success criteria or learning aims), sharing this interpretation with the learner, and co-deciding on the next steps to be taken (providing concrete guidance that will enable the learner to move forward in her learning journey).

The summative use of assessment information also relies on eliciting and interpreting evidence of learning. However, instead of negotiating next steps to support learning, the interpretation of evidence of learning in the summative use leads to an evaluative judgement (typically done by the teacher) which is communicated in the form of a number/grade. In this context summative assessment can be conceptualised as an evaluative judgement on performance at a specific point in time.

Both uses of assessment information have their own place in classroom learning, and they can be used to inform one another. This complementary relationship between the formative and summative use of assessment information provides a richer, more reliable, and more valid picture of learning.

Key message 4 Teachers need to be made clear of classroom assessment purposes and processes in the context of inquiry. This includes recognition and design of suitable assessment tasks which can be used for formative and/or summative purposes.

How did the ASSISTME project support classroom assessment of inquiry competencies?

ASSISTME provides a selection of examples of practice in assessing the development of inquiry competencies in science, mathematics, and technology at both primary and secondary education level.

ASSISTME focused on exploring teachers' and learners' use of four distinct classroom assessment strategies. These were interactions on-the-fly, structured classroom dialogue, teacher written-feedback, and peer written-feedback. Through developing tools, scaffolds and support for teachers, the ASSISTME project provided teachers with different opportunities to gather evidence of learning, interpret, and use it for formative and/or summative purposes.

Interactions on-the-fly

- Interactions on-the-fly are informal oral conversations that take place during a lesson that cannot be planned beforehand, but takes place spontaneously when the teacher recognizes appropriate opportunities to support students in advancing their learning. These can take place between the teacher and the learner, teacher and groups of learners, and teacher and the whole classroom.
- Interactions on-the-fly are characterised by the teacher (and sometimes learners) asking questions to elicit information, and by the subsequent use of questions (open- or close-ended) or comments (exploratory or instruction) to follow-up on the information that was gathered.
- Interactions on-the-fly are suitable to explore students' thinking and conceptual understanding, as well as to expose alternative conceptions.
- Interactions on-the-fly provide good opportunities for formative use of learning evidence, as the teacher can follow-up on this information in real-time and decide what is the best course of action to be taken.

Structured classroom dialogue

- Structured classroom dialogues are ritualised conversations that take place between the teacher and one focus-student, followed by a peer-feedback conversation led by a group of students.
- Structured classroom dialogue is characterised by the teacher asking a set of questions to which the focus-student is expected to provide an answer, and by peer-feedback questions or comments.
- All of these conversations take place in front of the remaining students in the class (who are encouraged to write their reflections on a structured work-sheet).
- Structured classroom dialogue is suitable to explore students' thinking and conceptual understanding, as well as to expose alternative conceptions. And it also provides an opportunity for developing students' metacognition and self-regulation.
- Structured classroom dialogue can be used both in a formative or summative way.

Interactions on-the-fly provide good opportunities for formative use of learning evidence, as the teacher can follow-up on this information in real-time and decide what is the best course of action to be taken. Alternatively, structured classroom dialogue is suitable to explore students' thinking and conceptual understanding, and provides an opportunity for developing students' metacognition and self-regulation. While each strategy has a place in classroom assessment, they can be integrated in different ways.

Teacher written-feedback

- Teacher written-feedback is a process that enables teachers to give feedback to students by writing comments on students work (written artefacts).
- Teacher written-feedback provides an opportunity to gather evidence of learning from an end-product (and can reveal students' thinking and understanding, as well as alternative conceptions).
- Teacher written-feedback can be used formatively to provide guidance towards next-steps in learning.
- Teacher written-feedback can be conceptualised as written dialogue between the teacher and the student that is more spread in time. Unlike interactions on-the-fly or structured classroom dialogue, which support formative action in real time, written feedback typically supports formative action in-between lessons.
- Teacher written-feedback can also be used in a summative way if the comments are used to make evaluative judgements on performance.

Peer written-feedback

- Peer written-feedback is a strategy that actively engages students in a process of assessing their peers' written work, of interpreting it against a set of success criteria, and of providing concrete guidance (regarding next steps in learning).
- Peer written-feedback provides an opportunity to gather evidence of learning from both assessors and learners, as well as providing opportunities for the development of students' metacognitive abilities and self-regulation.
- Students written artefacts contain evidence of their thinking and understanding. In addition, the assessor's comments and guidance also provide an insight into their own thinking and understanding.
- Peer written-feedback can support formative action in two distinct ways. One way is by supporting students' progression in learning through their peers's comments and guidance. The other way is by creating an opportunity for the teacher to decide on the next steps that will support both assessors and assesses, and plan activities accordingly in-between lessons.

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Implications for professional development

Teachers will engage with inquiry-based pedagogy and formative assessment with varying levels of confidence and expertise. The design and content of any professional development experience must respond to this. Key characteristics of professional learning arising from ASSISTME focus on providing teachers with an opportunity to:

- Develop an understanding of inquiry and how this understanding is translated into classroom practice.
- Develop an understanding of classroom assessment.
- Recognise and experience the kinds of teaching and learning activities that apprentice learners into inquiry and formative assessment. Inquiry-based pedagogy and formative assessment emphasise learner autonomy.
- Suggest approaches that can create formative assessment opportunities within an inquiry lesson. ASSISTME have explored four assessment tools that address this.
- Become familiar with and implement frameworks that enable a teacher to interpret learning and to evaluate progress in inquiry based on this.

- Explore teachers' personal understanding of the specific subject matter that underpins each individual inquiry. Most importantly, the professional development needs to address how personal subject knowledge can open up and limit formative interactions with learners.
- Identify and critically reflect upon their formative practice. This might entail sharing some specific examples of evidence of learning (e.g. student dialogue, written work, peer feedback), their evaluative judgement based on this evidence, next steps for this learner and how this was communicated.
- Develop and share classroom materials for enactment of inquiry activities and assessment of inquiry competencies. Teachers need support on how to adapt existing materials and develop new ones that support their teaching and assessment practices.

Key message 7 ASSISTME identifies a need for professional development that supports teacher understanding of formative assessment and inquiry-based teaching. The professional development should create opportunities for the establishment of a vital community of practitioners who can share good practice and their critical reflections of their practice.

Key message 8 Teachers need to be given time and opportunities for professional development. This is best approached through trialling and developing inquiry learning and assessment as a long term intervention through sharing experiences with other teachers, teacher educators, and researchers.

Key message 9 Classroom materials and assessment tools need to be made available, so that teachers can be supported in adopting and developing their own resources.

The teachers participating in ASSISTME across several European countries commented on the time, effort and persistence required to incorporate inquiry-based teaching approaches and different assessment tools within their current practice:

- In some instances, this approach challenged existing teacher perceptions of what inquiry learning looks like (autonomous, practical, authentic, collaborative) and the implications this has for assessment evidence (unpredictable, difficult to document on a whole-class basis, requires clear articulation of inquiry competencies, difficult to interpret on an individual student basis).
- In their reflections of their professional journey, ASSISTME project teachers highlight the demands of this approach, while still trying to satisfy the current teaching and assessment requirements of their particular cultural context.
- These teachers also identify the far-reaching benefits of the approach, the (sometimes eventual) positive response from their students and the enhancement of their (teacher) ability to capture, interpret and act on evidence of learning in inquiry contexts.

Key message 10 Our findings highlight the challenges teachers faced in adopting this practice. It requires a change in teaching philosophy for many teachers. Initially, this means putting in more time and effort into planning and resourcing. Teachers also go on to share the positive impact on their practice and their learners.