Ark of Inquiry: Inquiry Activities for Youth over Europe

Deliverable D1.2

Instruments for evaluating inquiry experiences, skills and societal responsibility – initial

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Legal Notices

Summary

The Ark of Inquiry aims to build a scientifically literate and responsible society through inquiry-based science education. The project seeks to expand young people's awareness of Responsible Research and Innovation (RRI) by sharing engaging inquiry activities in STEM domains across Europe and providing learners with meaningful feedback to improve their inquiry proficiency.

To arrive at a systematic evaluation of learners' development of their inquiry proficiency, an evaluation system is designed to assess their progress from a novice level of inquiry towards a basic and advanced level of inquiry. Inquiry proficiency is viewed to contain three aspects: (1) transformative inquiry skills, (2) regulative inquiry skills that raise scientific awareness, and (3) awareness of the role research plays in people's lives and society (RRI). Learners' proficiency is assessed across five inquiry phases.

Three forms of evaluation are embedded in the evaluation system: self-assessment, peer feedback, and teacher assessment (see Table 1). The three forms of assessment come together in a portfolio in which all the input and outcomes of the assessments are collected by the learner. The portfolio assesses the learner's progress in inquiry skills, in scientific awareness of the process of inquiry, and in becoming a responsible researcher that knows how to communicate and discuss processes and outcomes of scientific inquiry. The central assessment instruments are (1) a self-report form, (2) peer feedback form, (3) dialogue protocol, and (4) a summative level test. Protocols for keeping a portfolio and creating an Ark of Inquiry passport are provided, and the general assessment procedure is outlined.

In this deliverable, the theoretical principles of the evaluation system and its concrete instruments and procedures are described and presented in the form of downloadable documents. In a conclusive chapter recommendations for the implementation of the evaluation system are shortly discussed.

Table 1. *General framework of evaluation*

<table>
<tr><th rowspan="2">Inquiry Phase</th><th colspan="3">Inquiry Level</th></tr>
<tr><th>A (novice inquiry)</th><th>B (basic inquiry)</th><th>C (advanced inquiry)</th></tr>
<tr><td>ORIENTATION</td><td colspan="3" rowspan="5">PORTFOLIO:

Self-assessment (formative) -> self-report, products
Peer feedback (formative) -> written feedback
Teacher assessment (formative, summative) -> dialogue, tests</td></tr>
<tr><td>CONCEPTUALISATION</td></tr>
<tr><td>INVESTIGATION</td></tr>
<tr><td>CONCLUSION</td></tr>
<tr><td>DISCUSSION</td></tr>
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1. Introduction

The Ark of Inquiry project aims to build a scientifically literate and responsible society through inquiry-based science education. The project seeks to expand young people's awareness of Responsible Research and Innovation (RRI) by disseminating across Europe engaging inquiry activities. In the Ark of Inquiry inquiry activities are collected and disclosed for pupils in primary and secondary education to develop their inquiry proficiency and their meaningful understanding of the role that inquiry and science have in society and in their future professional lives (RRI). To encourage and support pupils to take challenges and develop their inquiry proficiency, three systems are developed in the Ark of Inquiry. An evaluation system is designed to assess the pupils' progress in inquiry proficiency (D1.2). An award system is designed to motivate pupils to take challenges and celebrate success (D1.3). And a support system is designed into the Ark of Inquiry to help teachers and pupils find their way in the Ark of Inquiry (D1.4). In this deliverable the principles, instruments and procedures of the evaluation system are described.

To come to an evaluation system, we first explore general theories of assessment and define what we mean by evaluation in the Ark of Inquiry (section 2.1). Then principles of an evaluation system are defined that provide a relevant, practical and effective starting point for assessment of inquiry proficiency in both secondary and primary schools (section 2.2). After that, the function of the evaluation system is defined by exploring in more detail what it is exactly that needs to be assessed. The Framework of Inquiry Proficiency (D1.1) serves as the starting point here to further develop assessment criteria for each phase and level (section 2.3). Finally, we translate the principles and functions of the evaluation system into concrete instruments and procedures (section 2.4) for teachers and pupils to work with. In a concluding chapter we summarize the central elements of the evaluation system and add some recommendations regarding its implementation and actual use in schools and for the way teachers could be prepared for its use in teacher training.

2. The Ark of Inquiry evaluation system

2.1 Introduction to the evaluation system

Evaluation, defined as the assessment of the starting level, progress and proficiency of learners, is a central process in education. Overall, assessment procedures serve two general goals in school learning. First, it serves the purpose of producing the information needed to diagnose pupils' prior knowledge and skills and adapt instructional designs and approaches according to their progress (formative assessment or assessment for learning). The key of formative assessment is to identify where the learner is in his or her learning, where (s)he is going, and which steps (s)he could take to get there (Wiliam, 2011; Hattie & Timperley, 2007). Formative assessment denotes moments and forms of assessment that aim at informing the process of learning and giving it new direction. These assessments are typically not graded. Types of formative assessment are: self-assessments; observations and interviews during or right after learning activities; reflective journals; and classroom presentations and discussions.

Second, it serves the formal purposes of accreditation, certification, and accountability both on the individual level of the learner and on the school level (summative evaluation *or* assessment of learning). Summative assessment is primarily aimed at giving credits and collecting evidence for mastery. Types of summative assessment are: exams, project reports, papers, and skills tests.

Traditionally, the teacher is seen as responsible for assessment. However, research has shown that formative assessment activates learners as owners of the learning processes and stimulates metacognition (Hacker, Dunlosky & Graesser, 1998), and motivation (Ryan & Deci, 2000). Recent reviews show evidence that formative assessment indeed steers students' learning (e.g. Bennett, 2011; Sluijsmans, Joosten-Ten Brinke, van der Vleuten, 2013).

In the Ark of Inquiry both formative (including diagnosis) and summative assessment are important. The function of the evaluation system in the Ark of Inquiry is twofold. First, the evaluation system monitors the progress pupils make in doing inquiry. In D1.1 we described inquiry proficiency as evolving from a novice (A) to a basic (B) and advanced (C) level[1]. Across those levels pupils become better in the so-called transformative inquiry skills such as formulating hypotheses, collecting data, and interpreting those data to reach evidence-based conclusions (Pedaste & Sarapuu, 2014). Levels and skills were summarized in the Framework for inquiry proficiency (D1.1). Second, the evaluation system seeks to evaluate

[1] In D1.1 the three levels are referred to as basis level (A), advanced level (B) and expert level (C) (D1.1, Tabel 1, p. 12). Since it is unlikely that pupils in high school will become true experts yet, the three level names are changed in novice level (A), basic level (B) and advanced level (C).

scientific inquiry awareness in the form of regulative (metacognitive) skills such as planning, monitoring and evaluating the inquiry process (De Jong & Njoo, 1992). Both the inquiry proficiency and the scientific inquiry awareness are assessed formatively and summatively.

The school contexts in which the evaluation system is going to function are diverse. The Ark of Inquiry as a platform will be used in thirteen different countries in both primary and secondary education. Therefore, it needs to be firmly based on theoretical principles that serve its purposes in all these contexts, and has to be easily accessible and user-friendly for both teachers and pupils. In the next sections we describe the principles and present detailed instruments and procedures worked out for the evaluation system.

2.2 Principles of the evaluation system

The Ark of Inquiry seeks to motivate and support pupils in order for them to take next challenges and develop their inquiry proficiency. For that purpose, the evaluation system needs to provide pupils with the right next steps to take (individual evaluation), and has to give teachers an up to date overview of their classrooms when it comes to mastery of skills and levels (collective evaluation). It needs to serve both the pupil (where do I stand, where am I going) and the teacher (where do they stand, where are they going). Given those demands, the evaluation system is built on three design principles outlined below: personalized learning, self-regulation, and community of learners.

The first principle is *personalized learning*. Personalized learning can be defined as an emerging pedagogical learning theory that takes differences between pupils as a starting point to tailor education to their needs. Pupils can differ in many ways, for instance, in gender and social backgrounds; general learning capacities and levels of mastery; interests and preferences for certain topics; and preferences for ways and moments of learning. Personalized learning seeks ways to adapt to those differences present in a classroom or other unit of learning to solve some structural problems in the educational system that are often associated with standardized learning settings, such as low effectiveness and success rates, low motivations, and underestimation of talents (e.g., Hargreaves & Shirley, 2009; Robinson, 2009). Personalized learning nowadays starts to appear in different forms ranging from individualized learning programmes in which teachers and/or technologies provide individual instructions and identify learning steps for individual pupils in a linear curriculum that is the same for all learners to settings in which learners themselves are in charge of choosing their learning objectives and steps to take in a community of peers and teachers. In practice, learning situations often show elements of both (Marquenie, Opsteen, Ten Brummelhuis & Van der Waals, 2014).

The role of assessment changes in personalized learning as compared to more standardized learning situations. In general, assessment in standardized curricula is often summative and

aimed at proving what has been learned (assessment of learning). In personalized learning the role of assessment is mainly formative and aimed at making progress visible in order to determine the next step to take in the learning process (assessment for learning). In the Ark of Inquiry the goal is for learners and teachers to be able to view their progress and decide which challenge to take next. Hence, central to the Ark of Inquiry is the *assessment for learning* approach as favoured by the principle of personalized learning.

The second principle is *self-regulation*, which can be defined as 'a systematic process of human behaviour that involves setting personal goals and steering behaviour toward their achievement' (Zeidner, Boekaerts & Pintrich, 2000, p. 751). The underlying assumption is that behaviour in the context of learning is goal-directed and controlled by some form of feedback. Self-regulation is about giving control to the learner, and it is claimed by research that feeling control and/or autonomy is beneficial for a learner's motivation and subsequently for its learning outcomes (e.g., Kuhl, 2000; Ryan & Deci, 2000). Self-regulation involves a number of sub-processes such as planning, choosing strategies, monitoring, time management, evaluation, and reflection. However, self-regulation is not given by birth and learners need to develop the skills involved in it. Development of self-regulation is viewed to evolve from observation and imitation to controlled display of skills in structured conditions towards self-regulation across changing environments and (unclear) conditions (Zimmerman, 2000).

From the perspective of an evaluation system, monitoring and evaluating one's own behaviour and reflecting upon it is closely related to self-assessment. Self-assessment is defined as a process in which learners judge their own learning, both the quality of the process as well as what is achieved (e.g., Boud & Falchikov, 1989). Self-assessment has been widely investigated in higher education, but has been found to be effective and motivating with young learners as well (e.g., Towler & Broadfoot, 1992). In the Ark of Inquiry, the pupil is tested in the beginning to determine his or her starting level. After that, the pupil decides – with the help of the teacher – which activity to do, to either practise long or only shortly within one level, when to take the summative level test, and so on. To be able to make those decisions, albeit with the help of the teacher, the learner needs to be able to self-assess his or her learning progress along the way. Therefore, the principle of self-regulation leads to the implementation of self-assessment in the evaluation system.

The third principle is becoming part of a *community of learning*. The Ark of Inquiry will be used by at least 23,000 pupils. This creates a community of learners across thirteen European countries, in which thousands of pupils are involved in doing inquiry, developing their inquiry proficiency as well as scientific and RRI awareness. A community of learning can be defined as a group of learners that share a learning purpose and meet (ir)regularly either live or through a platform to share and support each other (cf. Barab, Kling & Gray, 2004; Wenger, 1998). The sense of community springs from a feeling of membership and from participation in shared events. Communities of learning are often interdisciplinary so that

new opportunities for collaboration and learning arise. In this large community of learning pupils follow their own personal paths towards proficiency. Their first sense of community will spring from their own classroom mates who are also joining the Ark of Inquiry or from learners in their own regions and countries.

From the perspective of the evaluation system, the community of learning provides a rich context for creating a motivating and supportive culture in which pupils develop their proficiency. In this community of learners, pupils could provide each other with feedback on their work done. Peer feedback (or peer review) can be defined as learners giving quantitative and qualitative feedback on each other's work either orally or in writing. It has been found to be beneficial for both the reviewers and reviewed in many ways. It promotes collaboration, feeds pupils' abilities to monitor their own and others' work, enhances subject knowledge, and can positively influence their sense of autonomy and motivation (e.g., Liu & Carless, 2006; Nicol, Thomson & Breslin, 2014). Peer feedback is different from peer assessment, in which learners actually mark each other. Research has shown that learners often dislike giving marks to their peers because they doubt their expertise to be able to do so, and it brings on a shift in power relationships (Falchikov, 1995; Liu & Carless, 2006; Nicol, 2011). Both self-assessment and peer feedback are viewed to be important elements of assessment *for* learning that mutually reinforce each other (Topping, 2003).

Summarized, three principles of the evaluation system have been described, each leading to a form of assessment: personalized learning leading to an emphasis on assessment for learning (formative assessment), self-regulation leading to self-assessment, and community of learning leading to peer assessment.

2.3 Evaluation of inquiry proficiency

In D1.1 a *Framework for Inquiry Proficiency* was described. In that framework, inquiry is defined as consisting of five phases, and inquiry proficiency is viewed to develop across three levels of proficiency: a novice, basic, and advanced level. The levels are discerned based on three dimensions. First, pupils increasingly work with ill-defined and complex problems when moving along the levels and hence develop transformative inquiry skills. Second, pupils increasingly self-regulate their inquiry activities when moving from basic to more advanced levels of research and hence develop their awareness of the process of scientific inquiry. Third, pupils increasingly act out responsible research and innovation (RRI). Accordingly, the evaluation system has a threefold function, namely assessing pupils' inquiry proficiency and measuring their awareness of scientific inquiry (SA) and RRI. In this section, the framework for inquiry proficiency is worked out in a framework of evaluation containing criteria for assessment.

The framework of evaluation describes the main skills for each phase of inquiry and translates those skills to three levels of mastery. Level A (novice inquiry) concerns proficiency to follow a line of reasoning, variables and inquiry actions and develop a basic *understanding* of what is given. The skills are mainly concerned with receptive use of inquiry terminology and observing and/or imitating inquiry actions in simple and pre-structured instructions. Skills at level B (basic inquiry) concern proficiency to *formulate and explain* a line of reasoning and variables, produce simple plans and perform simple inquiry actions in a semi-structured environment. Level C (advanced inquiry) concerns proficiency to further *question and adjust* a line of reasoning, produce more complex plans and perform complicated inquiry actions in an ill-defined environment.

Table 2 presents the framework of evaluation. For each phase subskills are defined and translated to the three levels of mastery. All phases contain inquiry skills – transformative skills that show pupils' ability to do inquiry. Some phases also contain skills related to scientific awareness (SA) and awareness of responsible research and innovation (RRI). Scientific awareness is translated into regulative inquiry skills that express pupils' ability to plan, monitor and evaluate the process of doing inquiry. These regulative inquiry skills are spread across the inquiry phases: in the conceptualisation phase the pupil plans the inquiry activity, in the investigation phase the pupil monitors the inquiry process, and in the conclusion phase the pupil evaluates the process of inquiry. These regulative skills form the starting point for RRI awareness in the discussion phase of inquiry. In the context of the Ark of Inquiry RRI is defined as the attitude and ability to reflect on, communicate and discuss processes and outcomes of inquiry in terms of its relevance, consequences and ethics for oneself, others and society. In the discussion phase of inquiry, pupils' ability to reflect on, communicate and discuss the relevance, consequences and ethics of scientific research and inquiry outcomes is evaluated.

The award system further builds on the three dimensions of inquiry proficiency by nominating pupils with structural and strong performances and skills in light of inquiry, scientific and RRI awareness (see D1.3).

Table 2. *Detailed framework of evaluation*

INQUIRY PHASE	Skills	Criteria per Inquiry Level		
		A (novice inquiry) -> ability to understand	**B (basic inquiry) -> ability to formulate**	**C (advanced inquiry) -> ability to question**
ORIENTATION	explore topic	I can understand a short introduction	I can formulate an introduction	I can question an introduction
	state problem	I can understand a given problem statement	I can formulate a problem statement	I can question a problem statement
	identify variables	I can understand variables in a problem statement	I can formulate variables in relation to a problem statement	I can question variables in a problem statement
CONCEPTUALISATION	raise questions	I can understand a research question related to a problem statement	I can formulate a research question related to a problem statement	I can formulate a set of research questions related to a problem statement
	identify hypothesis	I can understand a hypothesis	I can formulate a hypothesis	I can formulate a set of hypotheses
	SA: research plan	I can understand a research plan	I can make and explain a research plan	I can question and adjust a research plan
INVESTIGATION	collect data	I can collect data according to prescribed procedures and fixed instruments	I can collect data according to my own procedures and instruments	I can collect data according to my own procedures and instruments
	analyse data	I can analyse data according to prescribed procedures	I can analyse data according to my own procedures for selecting, categorizing and summarizing	I can analyse a complex data set according to my own procedures for selecting, categorizing and summarizing
	formulate findings	I can understand findings	I can formulate and explain main findings	I can formulate and explain detailed findings
	SA: monitor	I can follow a research plan	I can explain my actions in relation to a research plan	I can question my actions and adjust a research plan

CONCLUSION	draw conclusions	I can draw main conclusions from findings	I can explain simple conclusions from findings	I can question detailed conclusions form findings
	relate findings	I can relate findings to research question or hypothesis	I can explain how findings relate to research question or hypothesis	I can question how findings relate to a set of research questions or hypotheses
	SA: evaluate	I know the five phases of inquiry and can describe my actions	I can describe the five phases and explain my actions	I can describe the five phases and cyclical nature of inquiry and question my actions
DISCUSSION	RRI: relevance	I can think about the applicability of findings	I can present and explain the applicability of findings	I can present and question the applicability of findings
	RRI: consequences	I can think about consequences of findings	I can present and explain consequences of findings	I can present and question consequences of findings
	RRI: ethics	I can think about my personal opinion on the consequences of findings for myself	I can present and explain a personal opinion on the consequences of findings for myself, others and society	I can question opinions on the consequences of findings for myself, others and society and discuss the importance of scientific inquiry for decision-making

The above framework of evaluation sets the criteria that will be used in all the evaluation instruments and procedures. The next section describes the instruments and procedures of evaluation.

2.4 Instruments and procedure

The framework of inquiry proficiency is built on the idea that pupils increasingly deal with more complex inquiry activities, processes of self-regulation (scientific awareness) and development of their RRI awareness. In the framework of evaluation this is translated into main skills for each phase of inquiry at the three levels of mastery. The framework for evaluation is the central point of reference used through the whole assessment process of formative and summative evaluation. The dashboard of assessment is a digital portfolio in which all moments of assessment and forms used are collected and triangulated. Below, the procedure and instruments are described. The concrete instruments can be found as appendices in the deliverable.

2.4.1 The portfolio (Appendices 1a and 1b)

Self-assessment, peer feedback and teacher assessment are triangulated in the central instrument of the evaluation system – the portfolio. A portfolio can be defined as a collection of products and assessments of a pupil that shows what the pupil has been doing, how the process went and what the results were (e.g., Venn, 2000). Because of the formative nature of assessment in the Ark of Inquiry, the portfolio also gives information about where the pupil is going to. Teachers and pupils use the portfolio as input for a formative assessment dialogue on progress in the Ark of Inquiry. If teachers and pupils at some point would like to create a paper portfolio, a front page can be created (Appendix 1a), and the nested folder structure can be used to create a table of content (Appendix 1b). The portfolio of each pupil consists of the following documents, which are described in detail in the following paragraphs:

1. passport
2. self-reports
3. products
4. peer feedback
5. dialogue reports
6. summative assessment tests

How to start a portfolio? After entering the Ark of Inquiry and getting a passport (paragraph 2.4.2), pupils (or teachers/school administrators) are instructed to create a folder on a local computer by the name 'Ark of Inquiry portfolio_name of pupil' as their central portfolio. In this folder, pupils collect their products or samples of products; self-assessments on processes and products; peer feedback on processes and products; and formative and summative teacher assessments on the processes and products. They do so by creating subfolders for each level. If the pupil starts to work at level A the first subfolder to create in the main folder is 'Level A'. In this folder, subfolders need to be created each time a new inquiry activity starts. In the activity folders, the actual assessments are collected. Working with a main folder and subfolders for each pupil helps teachers to have an overview in time of what their pupils have been doing. Hence, a nested structure of the portfolio for an entire classroom looks as shown on the next page (Figure 1).

Classroom X

Ark of Inquiry portfolio_Nancy

Level A

Activity 1

self-report.doc

peer feedback.doc

dialogue report.doc

product x, y, z

Activity 2

etc.

Ark of Inquiry portfolio_Wilbert

Ark of Inquiry portfolio_Amir

etc.

Figure 1. *A nested structure of the portfolio for an entire classroom*

2.4.2 Passport (Appendix 2)

Every pupil that starts to participate in the Ark of Inquiry receives an Inquiry Passport. In this passport the pupil gives some personal information. The passport also indicates the level the pupil is working at and the levels and awards obtained while progressing in the Ark of Inquiry (see also D1.3). When starting to work in the Ark of Inquiry pupils fill in the passport document and make a short personal description of their capabilities and interests concerning inquiry. They answer questions such as: What kind of researcher would I like to be? What do I like/not like about inquiry? What would I like to learn in the Ark of Inquiry? Then, the teacher provides all pupils with an entrance activity at level A. Special entrance activities are indicated in the Ark of Inquiry for each level. Those activities encompass all the phases of inquiry, so that pupil and teacher can formatively assess to what extent the pupil needs to work at the inquiry phases: does he or she need to learn, practise, or is the pupil already heading towards mastering, and how does this differ between phases? The pupil does the entrance activity and uses the self-report form to reflect on the proficiency. Then, teacher and pupil have a formative dialogue and decide how to proceed.

Example

Rebekka has entered the Ark of Inquiry and filled in her passport. She is provided with an entrance activity at A level. Rebekka does the activity and fills in a self-report. She discusses the self-report with the teacher. The teacher uses a dialogue protocol to structure the conversation and make a report on the outcomes. It shows that most inquiry phases are difficult for Rebekka, except for the orientation phase: she finds this easy to perform. Together they conclude that she indeed is a novice. Therefore, Rebekka continues on the A level and starts learning.

The above example describes a novice learner starting at the A level. However, it could also be the case that Rebekka performs far better than expected on the entrance activity and seems to master most skills at A level and some skills at B level already. In that case, the teacher and Rebekka would decide that she takes the summative A level test to show her mastery at A level. She collects the A level stamp in her passport if she passes the summative test, and proceeds with an entrance activity at the B level. Thus: *all* pupils start with an entrance activity at the A level and – if they stay actively involved in the Ark of Inquiry – proceed from A to B to C level eventually.

In general, learners build up their skills at each level in three steps. The first step is to *learn* to do inquiry at the preferred level. The aim here is to progress and succeed in doing the inquiry activity at the preferred level. The learner makes self-reports, collects peer feedback if wanted, and has formative dialogues with the teacher on the progress. Teacher and pupil can choose to focus on specific inquiry phases. The second step is to *practise* the inquiry skills at the preferred level. This means the learner proceeds in doing inquiry activities at the same level for at least one more time, until the learner feels he or she can do the entire inquiry process quite easily. Sometimes, specific inquiry phases need extra practising. Again, progress is followed by self-reports, and formative dialogue, sometimes peer feedback is collected. The third and final step to take is *feeling confident* that one has reached the level required for the entire inquiry process, and masters the skills at the preferred level. Teacher and pupil decide that it is time to take the summative level test. After teacher and learner have agreed the learner is ready to take the test, the learner is summatively assessed for the whole inquiry activity at the preferred level.

Summarized: in general, pupils do at least two entire inquiry activities per level: the entrance activity covering all phases, and the summative test activity covering all phases. If the entrance activity shows the pupil needs to learn or practise or feel more confident, the pupil does one or more additional activities at that level that might cover all or only some of the inquiry phases. When the formative dialogue shows the learner feels confident, the summative level test is taken. In the portfolio each inquiry activity is covered by at least a self-report and a dialogue report. Some activities are also covered by other products, such as peer feedback and inquiry outcomes. There are strict requirements for the summative level tests (see 2.4.7).

2.4.3 Self-report (Appendices 3a and 3b)

The start of the formative assessment is the self-report filled in by the pupil. The self-report aims at describing the nature and quality of the inquiry process as perceived by the pupil. In the self-report pupils write down what they have been doing, what they have learned and which questions they have after finishing the inquiry activity. They also indicate what they think the next step should be.

Two versions of the self-report form are developed: an A level and B/C level version. The A level version of the self-report (Appendix 3a) asks pupils to indicate their perception of what they have been doing and learning by ticking boxes of statements. The statements are based on the subskills/criteria of evaluation that were formulated at the A level (see Table 2). The language used in the form is simple and aimed at novice inquiry learners at primary and lower levels of secondary schools. The inquiry phases are implicitly present in the form as the underlying structure of the statements, as pupils develop their first awareness of the steps to take in inquiry.

The second version of the self-report (Appendix 3b) is more open and demands of pupils to state their progress for each inquiry phase. Hence, the pupils explicitly work with and within the five phases of inquiry while formatively assessing themselves. The B/C level form is expected to be suitable for basic and advanced inquiry learners and secondary school pupils. The second version is used at both the B and C level. However, at the C level a more extended report can be expected than at the B level. The teacher can support and challenge pupils to develop their metacognitive awareness of inquiry by asking questions that are increasingly complex and reflective. The dialogue protocol (2.4.6) helps the teacher to do so.

The self-report can be added by collected products (see 2.4.4) that provide further evidence on issues mentioned in the self-report. The self-report forms the main input for a dialogue between the pupil and the teacher, in which a collaborative conclusion on the performance is reached. Teacher and pupil indicate in the dialogue report if the pupil needs to learn, practise or work on feeling confident and if this goes for all phases or for some of them. The next step is decided.

2.4.4 Products

Pupils can add products as representations of inquiry processes and outcomes to their portfolio. These products are the result of one or more phases of inquiry, and provide evidence for how the pupil has been working and/or the quality of the work. Examples of products are:

- Category 1: inquiry outcomes
  For instance: designs/products, reports/articles (e.g., school paper, local newspaper), worksheets
- Category 2: communication and discussion materials
  For instance: powerpoint presentation, prezi, handouts, demos/promotion video
- Category 3: reflective materials
  For instance: written reflections on the process and outcomes of inquiry, instruments for data collection/analysis, samples of data (anecdotal evidence such as photos and videos)

In most cases it is not obligatory to add products to illustrate the process and/or quality of the inquiry activity. However, strict requirements for the summative level test are set (see 2.4.7). Also, teachers need to be aware of the evidence they find they need at some point once a learner has entered a level and starts learning by doing inquiry activities. If the teacher feels evidence is needed to show the learner's proficiency in one or more inquiry phases, this could be noted in the dialogue report and set as a requirement for the next inquiry activity (see also 2.4.6).

2.4.5 Peer feedback (Appendix 4)

Pupils can choose to collect peer feedback to show their mastery or originality of some kind and add this to the portfolio. Peers formatively assess pupils' quality of both process and product, by providing feedback on parts of the inquiry process or an inquiry product. For instance, a pupil has presented his or her inquiry activity in the classroom and collects feedback from one or two peers on the quality of the presentation and subsequent discussion.

The collection of peer feedback is neither obligatory nor always possible. Teachers should encourage pupils to provide each other feedback on presentations, for instance, so that a classroom culture of collaborative learning emerges.

2.4.6 Teacher assessment: dialogue report (Appendix 5)

After filling in the self-report the pupil and teacher have a formative assessment dialogue to see what the inquiry activity was about, how the pupil performed according to his own perceptions, and what the pupil needs next to proceed. In preparation of the dialogue the teacher reads the self-report and the other evidence that may have been collected by the pupil.

The teacher uses the dialogue protocol to start a reflective conversation with the pupil. The teacher asks questions related to the skills and criteria, and together with the pupil reaches a formative conclusion on the proficiency of each inquiry phase: is the pupil still working at the right level, is the pupil learning/practising/feeling confident, or is it time to take a summative level test? For each inquiry phase, teacher and pupil indicate the outcome of the dialogue on a continuum (Figure 2).

1. Orientation: explore a topic, formulate problem, identify variables

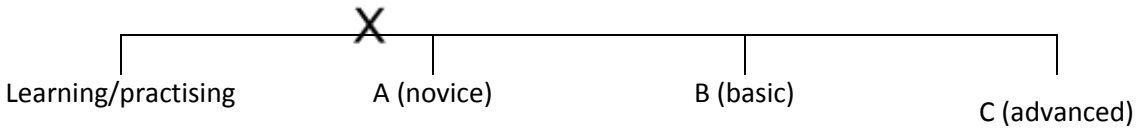

Figure 2. *Formative conclusion per inquiry phase (sample from dialogue protocol)*

The teacher writes down the conclusion of the discussion in the dialogue protocol, which is added as a report to the pupil's portfolio. Depending on the outcome of the dialogue, the pupil either continues at the same level practising one or more or all inquiry phases, or starts a summative level test. In addition, the outcome of the formative dialogue might be that the pupil is nominated for an award (see D1.3).

2.4.7 Summative level test (Appendix 6)

Until now, the learner has done an entrance activity and one or more inquiry activities to learn and practise inquiry at the preferred level. Teacher and pupil have now reached the conclusion that the pupil feels confident enough about doing inquiry at level x (A, B, or C), and that it is time to take the summative level test. For that purpose, the Ark of Inquiry contains summative assessment activities that cover all phases of inquiry at the same level (WP2). These summative assessment activities are used to test the pupil's inquiry proficiency and scientific and RRI awareness according to the criteria set for that level. The summative assessment activities are inquiry cases that the learner needs to solve. To prove mastery, the learner has to provide a strict set of evidence: a self-report, at least two products from two different categories (see 2.4.4), and at least one peer feedback form (2.4.5). After handing in all the required evidence the teacher assesses the work of the pupil by filling in the teacher form for summative assessment that can be found in Appendix 6.

2.4.8 General assessment procedure (Appendix 7)

The evaluation system needs to be functional in both primary and secondary education in thirteen different countries that have variable experience with inquiry learning and formative evaluation. To a lesser extent, pupils will use the inquiry activities from their homes. In all situations of usage, pupils will have the lead in self-assessing their inquiry activities but collaborate with teachers and, to a lesser extent, with peers in the formative and summative assessment procedures. Hence, the evaluation system is aimed at self-regulated learning by individuals who can work independently on inquiry activities but need their teachers and peers for assessment. To support both independency and collaboration, its instruments should be readily available and easily accessible in different contexts. It should be set up in a lean way so that schools from different countries can easily access and use the systems in combination with their own local systems. The evaluation system should be able to function without a large and complex administrative database, easily allowing teachers and pupils to get an overview of steps taken and success achieved.

To keep the evaluation system clear and simple, it consists of downloadable documents that are implemented locally. This means that teachers and pupils use forms as files to be stored at folders on local school servers. For instance, pupil Theresa enters the Ark of Inquiry and is subscribed in the system. The teacher is instructed to make a personal folder Ark_Theresa at the local server which will start to function as Theresa's portfolio. Whenever Theresa starts a new inquiry activity, she downloads a new formative assessment form that she uses during the activity and saves in her personal Ark of Inquiry folder. She can also save products that spring from the inquiry activity in this folder, and peer feedback. The teacher uses this folder

to prepare a formative assessment dialogue with the pupil. The teacher and pupil instructions for starting and using a portfolio are summarized in Figure 3.

Step 1	Teacher creates portfolio folder at local server (Ark_Pupil name)
Step 2	Pupil fills in passport document and saves this (Ark_passport_Pupil name)
Step 3	Pupil starts entrance activity at level A (storing outcomes in portfolio folder Level A / Activity 1)
Step 4	Formative assessment of entrance activity
	Pupil either proceeds at level A or takes summative A level test and proceeds to level B
Step 5	Pupil conducts inquiry activities and formative assessment of those activities
	Learn, practise, feeling confident -> summative level test
	(storing outcomes in portfolio folders Level A / Activity 2, 3, etc. ; Level B / Activity 1, 2, 3, etc.)
Step 6	Pupil takes summative level tests assessed by the teacher

Figure 3. *Main steps in a general evaluation procedure*

3. Conclusions

3.1 Summary

The function of an evaluation system in the Ark of Inquiry is twofold. First, the evaluation system monitors the progress pupils make in doing inquiry. We described inquiry proficiency as evolving from a novice (A) to a basic (B) and advanced (C) level. The levels and associated (sub)skills were summarized in the framework for evaluation in which the skills are translated to assessment criteria per level. Second, the evaluation system seeks to evaluate scientific inquiry awareness in the form of regulative (metacognitive) skills such as planning, monitoring and evaluating the inquiry process. The associated skills are mentioned in the framework for evaluation under the inquiry phases 'conlusion' and 'discussion'. The evaluation system assesses both formatively and summatively. Formative assessment will be used to foster and stimulate progress in proficiency; summative assessment will be used to measure proficiency and give a certain 'certification' to the pupil with which he or she can start at the next proficiency level. The evaluation system is built on three principles that lead to the implementation of three forms of assessment:

1. *personalized learning*: within the principle of personalized learning differences between pupils are taken as a starting point to tailor education to the individual needs of pupils. In personalized learning the role of assessment is mainly formative and aimed at making progress visible in order to take the next step in the learning process. The principle of personalized learning leads to formative assessment in the evaluation system.

2. *self-regulation*: within the principle of self-regulation pupils set personal goals and steer on their behaviour in order to reach an achievement. From the perspective of the evaluation system, monitoring and evaluating one's own behaviour and reflecting upon it are closely related to self-assessment. Therefore, the principle of self-evaluation leads to the implementation of self-assessment in the evaluation system.

3. *community of learners*: within the principle of community of learners a group of learners that share a learning purpose share and support each other through a platform. From the perspective of the evaluation system, a community of learners provides a rich context for creating a motivating and supportive culture. Therefore, the principle of community of learning leads to the implementation of peer feedback.

To be able to monitor the progress pupils make in doing inquiry and to be able to decide what is the best next step to develop their inquiry skills, scientific and RRI awareness, pupils make use of a portfolio (Appendix 1a and 1b). This portfolio contains information about the pupil and his or her current proficiency, about the activities he or she has performed and is performing and about his or her development. When a pupil enters the Ark of Inquiry he or

she performs an entrance activity at the A level in order to obtain a Passport (Appendix 2). This activity gives an insight in the current proficiency level and is used by both the teacher and the pupil to decide which step to take next.

For each inquiry activity the pupil performs he or she will create a folder in his or her personal portfolio. When the pupil has finished performing the activity he or she places a self-report (Appendix 3) in the portfolio and might add other products and peer feedback (Appendix 4). Making use of all the information in the portfolio, the teacher prepares a formative assessment dialogue with the pupil. This dialogue is documented and also put in the portfolio (Appendix 5). When the pupil and the teacher decide that the pupil is ready to take a summative inquiry test, the pupil performs a summative inquiry activity. The teacher assesses this activity by filling in the summative assessment form (Appendix 6). When the pupil has proved to master the level, he or she gets a 'stamp' in his or her passport that will allow the pupil to continue in the Ark of Inquiry. A general assessment procedure (Appendix 7) indicates how all the instruments are combined and organized.

This deliverable presents only one version of the instruments and procedures in the evaluation system whereas the Ark of Inquiry will be used in different school settings varying from primary to secondary schools, in different countries, and with different amounts of experience with inquiry learning and formative assessment. The instruments have been kept simple in their use of language and it is expected that they can be used in all those different contexts by pupils of different age levels (and related language and thinking abilities). Moreover, most of the instruments are mainly used by the teachers or by teachers and pupils together and therefore do not need specific versions. The self-report is the only instrument that has two versions: a structured A level version that can be used by novice inquiry learners and pupils in primary schools, and a less structured and more complex B/C level version that can be used by basic and advanced inquiry learners at primary and secondary schools.

3.2 Recommendations for implementation

The evaluation system has been set up as transparent as possible given the complex nature of inquiry and its assessment. However, most teachers and pupils will not be used to work with formative assessment instruments. Although the number of instruments and procedures is limited, the expectation is that teachers and pupils will need to learn to work with it. Within the Ark of Inquiry, two support mechanisms are present to help teachers and pupils adopt the evaluation system. First, the Ark of Inquiry platform will have teacher training materials and support materials for both teachers and pupils available that help introduce and explain the essentials of the principles of the evaluation system, and show how to work with the instruments. These materials will contain a presentation of the framework of inquiry proficiency and descriptions of the principles, instruments, and

procedures of the evaluation system as well as worked out examples of its usage in schools. The worked out examples will be developed in collaboration with teachers. They illustrate with concrete cases taken from primary and secondary classrooms how teachers and pupils work with the evaluation system, and what the effects are.

Second, the Ark of Inquiry will be implemented in schools through training teachers (WP4). In teacher training explicit attention will be paid to the principles, instruments and procedures of the evaluation system. In many countries and schools assessment is often summative and aimed at certification. Moreover, the teachers are in charge of the assessment process and not the pupils. The principles of the Ark of Inquiry promote self-assessment, peer feedback and formative assessment dialogues as central assessment mechanisms. Most of the teachers and pupils will not be used to this and need to be carefully introduced to the principles and procedures of formative evaluation to help them learn to apply it successfully. Therefore a central element of teacher training will be learning to work with the evaluation system.

To further facilitate and support successful implementation of the evaluation system, piloting of the instruments and procedures presented in this deliverable is planned. Two phases of piloting are planned within the next year. First, a small group of teachers and pupils of primary and secondary schools will be asked to participate in paper walk through sessions in which the teachers and pupils are asked to think aloud while reading and looking through the instruments and procedures and while thinking about concrete use in their own classrooms. The questions and comments of the teachers and pupils will be collected and analysed to help us fine-tune the instruments and procedures before their first actual use. The main research questions of the paper walk through relate to the *perceived* relevance and practicality of the instruments and procedures by primary and secondary school teachers and pupils.

Second, in the second half of the year the evaluation system will be evaluated in a small scale pilot in seven countries (WP6). Five schools with at least three teachers per country will use the Ark of Inquiry and evaluation system. The outcomes of this pilot will be used to improve the instruments and procedures. The main research questions of the paper walk through relate to the *realized* relevance and practicality of the instruments and procedures by primary and secondary school teachers and pupils.

Finally, the evaluation system is not only aimed at a future in which inquiry learning is omnipresent in science education, but at a future in which learning and assessment *for* learning turn into inquiry processes themselves.

4. Appendices

4.1 Appendix 1a. Front page of portfolio

Ark of Inquiry

Portfolio

Name:

4.2 Appendix 1b. Table of Contents of portfolio

Table of Contents (example)

Passport

Level A

1.1 Inquiry activity 1

1.1.1 Product of the inquiry activity

1.1.2 Self-report form

1.1.3 Dialogue report

1.1.4 Peer-feedback form

1.2 Inquiry activity 2

1.2.1 Product of the inquiry activity

etc.

1.x Summative level test

1.x.1 Product of the inquiry activity

1.x.2 Product of the inquiry activity

1.x.3 Peer feedback form

1.x.4 Summative assessment form

Level B

etc.

4.3 Appendix 2. Passport document

Welcome to the Ark of Inquiry!

Name: Boy / Girl

Age:

Date of entrance:

Who am I?

My interests are:

I like / dislike research because:
What I would like to do and learn in the Ark of Inquiry is:

Stamps for obtained levels:

A	B	C
		

Obtained awards:

4.4 Appendix 3a. Self-report form A level

Self-report A level (novice)

Name and level of the inquiry activity:

(1) What did you think of the inquiry activity?

⓾ I liked it	⓾ I disliked it
Because:	

(2) What did you do? Tick the boxes of the activities you did.

○ I read an introduction to the topic

○ I read a problem statement

○ I learned about variables in the problem statement

○ I read a research question(s) and understood its relation to the problem statement

○ I read a hypothesis and understood its relation to the research question

○ I understood the steps to be taken in the inquiry activity (research plan)

- ○ I collected data according to prescribed procedures and fixed instruments
- ○ I analysed data according to prescribed procedures
- ○ I collected findings
- ○ I followed a research plan
- ○ I drew conclusions from the findings
- ○ I related the findings to the research question / hypothesis
- ○ I gained insight in the different steps of doing inquiry
- ○ I thought about the applicability of the findings
- ○ I thought about the consequences of the findings
- ○ I thought about my opinion on the consequences of findings for myself and others

(3) What did you learn? Answer the questions below.

How do you think things went? What did you find easy/difficult?
Do you have any questions for the teacher?
What would you like to do next? ○ learn / practise more -> next inquiry activity

O learn / practise more -> specific topics or activities: …

O take summative level test

4.5 Appendix 3b. Self-report form B/C level

Self-report (B/C level basic/advanced)

The self-report contains all inquiry phases. You only need to fill in the part(s) that you need.

Name and level of the inquiry activity:

General reflection: what did you think of the inquiry activity?

1. Orientation

The orientation phase is a process to stimulate curiosity about a topic, and it results in a problem statement. Orientation consists of the skills: explore a topic, state a problem, and identify variables.

Your reflection

2. Conceptualisation

In the conceptualisation phase research questions and/or hypotheses are stated. Conceptualisation consists of the skills: raise questions, identify hypothesis, and make a research plan.

Your reflection:

3. Investigation

The investigation phase is a process of gathering empirical data to resolve the research question or hypotheses. Investigation consists of the skills: collect data, analyse data, formulate findings and monitor the process.

Your reflection:

4. Conclusion

In the conclusion phase research findings are reported and justified by the results of the investigation. Conclusion consists of the skills: draw conclusions, relate findings, and evaluate the process.

Your reflection:

5. Discussion

The discussion phase consists of reflection, communication and discussion. Discussion consists of the skills: considering the relevance, consequences and ethics of findings.

Your reflection:

Overall conclusion over the inquiry process

Pick a point on the line that you think denotes your level of mastery and explain why.

Explanation

4.6 Appendix 4. Peer feedback form

Peer feedback

Name of reviewer: Date:

Name of reviewed:

Which products and/or processes did you see?

TOPS: what did you see that was really good?

TIPS: if you were the teacher, which tips would you have for improvement?

4.7 Appendix 5. Teacher assessment: dialogue protocol

Dialogue report

Consider the self-report and other assessment products before starting the dialogue. Proceed according to the following steps *per inquiry phase:*

STEP 1 Evaluate inquiry proficiency by asking the pupil to describe and show what he or she has been doing. Use the skills and criteria to deepen the conversation.

STEP 2 Reflect on the process of scientific inquiry by asking the pupil how the inquiry phase went, what was easy/difficult, and what was liked/disliked.

STEP 3 Challenge the pupil's thinking about the applicability of inquiry outcomes by asking the pupil if the inquiry activity could be used by others and if it raised any questions about usefulness or ethical use.

STEP 4 Come to a conclusion on the quality of the work:

Indicate for each phase if the pupil is learning / practising / starting to feel confident

- orientation
- conceptualization
- investigation
- conclusion
- discussion

Indicate if the pupil needs to further learn / practise / start to feel confident (next step)

Indicate if the next activity should focus on certain inquiry phases: yes / no (explain)

Indicate if the pupil is ready to take a summative level test: yes / no

4.8 Appendix 6. Summative assessment form

Summative assessment [name] [level]

The assessment form consists of five parts, one for each inquiry phase. Each subskill needs to be assessed at the A level to obtain the A level and to be allowed to start practicing at the B level. Each subskill needs to be assessed at the B level to obtain the B level and to be allowed to start practicing at the C level. Each subskill needs to be assessed at the C level to obtain the C level and become an advanced inquiry learner.

Indicate which evidence was used for the assessment (note that the following pieces of evidence need to be present: self-report, at least one peer feedback, and at least two products from two different categories):

- self-report
- peer feedback (number ...)
- category 1: inquiry outcomes, namely ….
- category 2: communication/discussion materials, namely ….
- category 3: reflective materials, namely ….

1. Orientation

The orientation phase is a process to stimulate curiosity about a topic, and it results in a problem statement. Mark for the below skills what fits the most at this moment.

Explore a topic

o The pupil cannot yet understand a short introduction to a topic

A The pupil can understand a short introduction

B The pupil can formulate an introduction

C The pupil can question an introduction

State problem

o The pupil cannot yet understand a given problem statement

A The pupil can understand a given problem statement

B The pupil can formulate a problem statement

C The pupil can question a problem statement

Identify variables

o The pupil cannot yet identify variables in a problem statement

A The pupil can understand variables in a problem statement

B The pupil can formulate variables in relation to a problem statement

C The pupil can question variables in a problem statement

Explanation

2. Conceptualisation

In the conceptualisation phase research questions and / or hypotheses are stated. Mark for the below skills what fits the most at this moment.

Raise questions

0 The pupil cannot yet understand a research question related to a problem statement

A The pupil can understand a research question related to a problem statement

B The pupil can formulate a research question related to a problem statement

C The pupil can formulate a set of research questions related to a problem statement

Identify hypothesis

o The pupil cannot yet understand a hypothesis

A The pupil can understand a hypothesis

B The pupil can formulate a hypothesis

C The pupil can formulate a set of hypotheses

SA: Research plan

o The pupil cannot yet understand a research plan

A The pupil can understand a research plan

B The pupil can make and explain a research plan

C The pupil can question and adjust a research plan

Explanation

3. Investigation

The investigation phase is a process of gathering empirical data to resolve the research question or hypotheses. Mark for the below skills what fits the most at this moment.

Collect data

o The pupil cannot yet collect data according to prescribed procedures and fixed instruments

A The pupil can collect data according to prescribed procedures and fixed instruments

B The pupil can collect data according to his or her own procedures and instruments

C The pupil can collect data according to his or her own procedures and instruments

Analyse data

o The pupil cannot yet analyse data according to prescribed procedures

A The pupil can analyse data according to prescribed procedures

B The pupil can analyse data according to his or her own procedures for selecting, categorizing and summarizing

C The pupil can analyse a complex data set according to his or her own procedures for selecting, categorizing and summarizing

Formulate findings

o The pupil cannot yet identify the main findings in a familiar topic

A The pupil can understand findings

B The pupil can formulate and explain main findings

C The pupil can formulate and explain detailed findings

SA: monitor

o The pupil cannot yet identify the main findings in a familiar topic

A The pupil can follow a research plan

B The pupil can explain his or her actions in relation to a research plan

C The pupil can question his or her actions and adjust a research plan

Explanation

4. Conclusion

In the conclusion phase research findings from the inquiry are reported and justified by the results of the investigation. Mark for the below subskills what fits the most at this moment.

Draw conclusions

o The pupil cannot yet draw main conclusions from findings

A The pupil can draw main conclusions from findings

B The pupil can explain simple conclusions from findings

C The pupil can question detailed conclusions from findings

Relate findings

o The pupil cannot yet relate findings to research question or hypothesis

A The pupil can relate findings to research question or hypothesis

B The pupil can explain how findings relate to research question or hypothesis

C The pupil can question how findings relate to a set of research questions or hypotheses

SA: evaluate

o The pupil does not yet know the five phases of inquiry and cannot describe his or her actions

A The pupil knows the five phases of inquiry and can describe his or her actions

B The pupil can describe the five phases and explain his or her actions

C The pupil can describe the five phases and cyclical nature of inquiry and question his or her actions

Explanation

5. Discussion

The discussion phase consists of reflections on findings in terms of relevance, consequences, and ethics. Mark for the skills below what fits the most at this moment.

RRI: relevance

o The pupil cannot yet think about the applicability of findings

A The pupil can think about the applicability of findings

B The pupil can present and explain the applicability of findings

C The pupil can present and question the applicability of findings

RRI: consequences

o The pupil cannot yet think about the consequences of findings

A The pupil can think about consequences of findings

B The pupil can present and explain consequences of findings

C The pupil can present and question consequences of findings

RRI: ethics

o The pupil cannot yet think about his or her personal opinion on the consequences of findings for himself or herself

A The pupil can think about his or her personal opinion on the consequences of findings for himself or herself

B The pupil can present and explain a personal opinion on the consequences of findings for himself or herself, others and society

C The pupil can question opinions on the consequences of findings for himself or herself, others and society and discuss the importance of scientific inquiry for decision-making

Explanation

PASSED or FAILED

Overall conclusion: failed / passed level test?

4.9 Appendix 7. General assessment procedure

General assessment procedure

This document contains the general procedure for starting and using a portfolio. All the forms, descriptions of the inquiry activity and products will be saved in the portfolio.

1. When entering the Ark of Inquiry the teacher makes for each pupil a personal folder at the local server (e.g. Ark_Theresa). This is the portfolio.

2. The pupil fills in the passport document

3. The pupil starts the entrance activity at level A. Work is saved in subfolder Level A -> Entrance activity. Formative assessment follows and indicates if the pupil continues the next activity at level A or does the summative level A test.

4. For each activity the pupil starts, the next steps are repeated:

    a. the pupil performs the activity
    b. the pupil adds self-report and products to the subfolder for this activity
    c. formative dialogue: evaluation of the progress made by teacher and pupil. Conclusion on the dialogue report, either continue at the same level, or do a summative level test.

5. If pupil and teacher agree the pupil masters the level the pupil takes the summative level test. The teacher downloads the summative inquiry activity that fits the level of the pupil.

6. The pupil performs the summative inquiry activity and adds the required evidence to the portfolio in a folder ‘summative level test’ in folder Level x.

7. If the pupil achieves the summative level test, (s)he proceeds to the next level. A level stamp is added to the passport.

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