



Ark of Inquiry: Inquiry Activities for Youth over Europe

Deliverable D1.4

# Specification of support systems in Ark of Inquiry – initial

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## Summary

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 sharing engaging inquiry activities in STEM domains across Europe, providing learners with meaningful feedback to improve their inquiry proficiency, and preparing pupils to engage constructively in socio-scientific discussions. With the help of supporters pupils will advance in the Ark of Inquiry towards open-ended inquiry problems and self-directed learning and acquire crucial skills needed to critically evaluate new research and innovation when cultural, environmental, social, economic or ethical values are at stake.

This deliverable describes support mechanisms to help engage more pupils in inquiry activities, stimulate wider views on research, support pupils in starting and completing the envisaged activities on time, and motivate them to take up challenges set by the Inquiry Awards system. The general principles presented in this deliverable provide direction for work to be done in the upcoming Work Packages (WPs) WP3 (Supporting community) and WP4 (Training). In WP3 the principal objective is to create two communities (a community of research institutions, science centres & museums and a community of teachers) who both motivate and engage pupils in the Ark of Inquiry. In WP4 the objective is to develop the appropriate training and guidance materials to support the work of these communities. More specifically, WP4 identifies teacher educators/researchers, teachers, pupils, and parents as the main stakeholders for which supportive materials will be developed.

On the whole, supporters require a shared understanding of how pupils' inquiry skills and RRI awareness is supported in the Ark of Inquiry. In order to facilitate work in WP3 and WP4 so that it integrates smoothly with the overall framework of Ark of Inquiry this deliverable describes initial specifications of support mechanisms. It derives from the principles set in deliverables D1.1 (Description of inquiry approach that fosters societal responsibility) and D2.1 (Criteria for selection of inquiry activities including societal and gender dimensions), as well as recent work in D1.2 (Instruments for evaluating inquiry experiences, skills and societal responsibility), D1.3 (Description of the system of Inquiry Awards that foster responsibility) and D2.2 (Pedagogical inquiry scenarios for re-use of inquiry activities). This initial specification of support systems in Ark of Inquiry will be updated in month 24.

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# 1. Introduction

This deliverable aims to specify the support system for the Ark of Inquiry project. The main objective is to engage and motivate pupils, teachers and other supporters to be a part of the Ark of Inquiry. Support mechanisms are orientated towards aligning the Framework of Inquiry Proficiency developed in deliverable D1.1 and other key works in the Ark of Inquiry project (D1.2, D1.3, D2.1 and D2.2). In general, support systems focus on facilitating inquiry learning and awareness of Responsible Research and Innovation (RRI).

This deliverable is divided into the following sections. First, we discuss the purpose of a support system in Ark of Inquiry. Then we discuss the three major areas where the support systems are applied: support for inquiry learning, support for RRI and support for the Ark of Inquiry platform. Each of these areas is discussed fully and guidelines are described to help direct future work in work packages WP3 and WP4. Finally, the conclusion section summarizes the main outcomes of this deliverable.

## 2. Ark of Inquiry Support System

The purpose of a support system in the Ark of Inquiry is to help pupils, teachers and other supporters get engaged and motivated in inquiry activities, Responsible Research and Innovation, and the Ark of Inquiry platform. The support system's role is to provide guidelines and assistance for the inquiry learning framework and awareness of RRI. Support appears in an either explicit or implicit form. Explicit support is specific procedural directions or a set of written/verbal instructions. Implicit support is, however, embedded into the design of support materials and encourages accomplishing tasks through indirect guidance (Paul, Podolefsky & Perkins, 2012). For example, explicit support can be a guiding statement to support the inquiry skill of formulating a scientific research question, i.e. "a research question is a question that contains independent and dependent variables". Implicit support can be the functionality of the Ark of Inquiry platform to offer links to online forums where pupils ask questions about inquiry activities.

### 2.1 Support for Inquiry Learning

Support for inquiry focuses on the Framework for Inquiry Proficiency developed in deliverable D1.1. Within this framework specific inquiry skills for each of the different inquiry phases are defined. These phases involve transformative and regulative knowledge and skills (Hulshof & de Jong, 2006; Njoo & de Jong, 1993).

Research has shown that inquiry learning may be difficult for novice learners because of a low level of their transformative and regulative knowledge, poor level of inquiry skills, or an increase in their cognitive load (Paas, Renkl & Sweller, 2004; Sandoval & Reiser, 2003; Veermans, van Joolingen & de Jong, 2006). In addition, teachers may require support for using an inquiry approach because they may have a weak understanding of the nature of science or because they report they are teaching according to an inquiry approach when in fact they are not (Capps & Crawford, 2013; Kidman, 2011). Therefore, there is a need to design and develop relevant support materials that help both teachers and pupils to accommodate their teaching and learning methods.

Teacher training is needed to actually implement these support materials in practice. Most of this support is realized in the form of web-based materials and teacher training materials that will be concretely developed in WP4. Both the web-based and teacher training materials explicitly help teachers to support the development of pupils' inquiry proficiency while presenting possibilities of giving motivational support and feedback to pupils about their progression and success related to transformative, regulative and RRI skills.

## 2.1.1 Framework for Inquiry Proficiency

The Framework for Inquiry Proficiency shows how the inquiry phases are related to three levels of proficiency (novice, basic, and advanced)<sup>1</sup>. The levels of proficiency were created based on taking into account three dimensions: (1) problem-solving type (progressing from well- to ill-defined problems), (2) learner autonomy (progressing from teacher/material-led to pupil-led processes), and (3) RRI awareness (progressing from sharing with a small audience to discussions and interactions with a broad audience of stakeholders).

There are five inquiry phases: Orientation, Conceptualisation, Investigation, Conclusion, and Discussion. The support system provides guidelines about the necessity of each phase considering the Framework for Inquiry Proficiency. Also, guidelines are provided about sequencing the inquiry phases considering pedagogical scenarios and available Ark of Inquiry activities. These guidelines must also take into account the inquiry proficiency levels (novice, basic, and advanced). Thus, support acts as a scaffold whereas learners at the novice level receive more guidance than learners at higher levels of inquiry proficiency. This support is provided primarily in explicit support form by, for instance, teacher guidelines or implicit support form by, for instance, more or less structured evaluation instruments (D1.2). For example, an explicit guideline for a teacher to explain to a pupil about the necessity of the Conclusion inquiry phase is to state “the Conclusion phase is necessary to finalize your analysis of your investigation results and answer your research question or to confirm/disconfirm your hypotheses.” For example, an implicit guideline is present in the dialogue form used in the evaluation system that aims at evaluating pupils’ effort to conclude analyses with findings and relating those findings to hypotheses.

## 2.1.2 Inquiry Skills

Each inquiry phase is further defined by particular inquiry skills. Inquiry skills can be divided into two types: transformative and regulative. Transformative inquiry skills include identifying a problem, formulating a research question, formulating hypotheses, planning the collection and analyses of data, and drawing conclusions (Pedaste & Sarapuu, 2014). Support for inquiry skills can take into account the different inquiry proficiency levels and therefore also vary. The guidelines for inquiry skills consist of a list of definitions, components, examples, and actions. Appendix 1 presents example guidelines for supporting pupils’ transformative inquiry skills. These guidelines can become part of the explicit support in web-based and training materials for teachers and pupils.

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<sup>1</sup> In D1.1 the three proficiency levels are referred to as basic level (A), advanced level (B), and expert level (C) (see D1.1, Table 1, p. 12). Since it is unlikely that pupils in high school will get to expert level, the three levels have been changed to novice level (A), basic level (B) and advanced level (C).

Regulative skills include planning, monitoring and evaluating (de Jong and Njoo, 1992). Transformative skills require cognitive capabilities while regulative skills require metacognitive capabilities. Appendix 2 presents example guidelines for supporting pupils' regulative inquiry skills.

## 2.2 Support for RRI

The Framework for Inquiry Proficiency introduced in Ark of Inquiry deliverable D1.1 described a gradual development of RRI awareness in pupils through increasingly multi-faceted interactions with social actors in the research and innovation process. Emphasis was placed on communicating the outcomes of inquiry and their relevance. By sharing their inquiry experiences with others and discussing potential implications and societal expectations with regard to an inquiry activity, pupils develop RRI awareness, which prepares them later in life to participate constructively in socio-scientific discussions. Hand and Levinson (2012) argue that discussion is the most advantageous teaching strategy for learners to approach controversial issues since discussion stimulates multiple points of view, evokes reactions to opinions other than your own, and fosters a deeper understanding of the topic.

Support for the development of RRI awareness in Ark of Inquiry is built up in several ways. First, teachers are supported with materials/guidance to teach essential inquiry skills related to anticipating and assessing potential implications and societal expectations with regard to research and innovation. Next, teachers are supported to foster classroom dialogues and group work, in which communication and discussion are practiced by pupils, and in which pupils actively interact amongst their peers. Third and finally, teachers are supported to facilitate pupil interactions with informal educators. All three forms of support for teachers to stimulate and facilitate RRI awareness and activities are deemed important in relation to the award system of the Ark of Inquiry. The award system, which is described extensively in D1.3, focuses on pupils' RRI performances and grants awards (bronze, silver and gold medals) to those pupils who successfully embed RRI activities in their inquiry processes. In D1.3 RRI awareness and skilfulness 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.*

All in all, support for RRI awareness focuses on providing teachers with effective pedagogical practices that will gradually expand pupils' inclination to develop RRI activities that consist of reflection, communication and discussion and hence engage them in Responsible Research and Innovation.

## 2.2.1 Inquiry Skills and RRI Awareness

Before pupils begin to personally interact with societal actors to expand their awareness of RRI, they require a basic understanding of inquiry processes and familiarity with typical outcomes of inquiry. Thus, as already described in Section 2.1, teachers are supported with materials/guidelines to introduce inquiry to their pupils. For example, it was mentioned that teachers can support pupils' inquiry by prompting them with open-ended questions to stimulate thinking. Also, teachers can guide inquiry learning more explicitly by providing specific instructions.

In terms of developing RRI awareness teachers who are implementing an inquiry activity can highlight questions that relate to the relevancy, consequences and ethics of the inquiry activity. For example, questions about the relevancy can include 'What problem does the inquiry activity solve and what need does it address related to you, others and society?' and 'Who uses (or will use) the outcomes of the inquiry activity?' Questions about the consequences of an inquiry activity include 'How are the outcomes of the inquiry activity of use to yourself, others and society?' and 'What are the side effects for yourself, others and society?' Finally, questions related to the ethics of an inquiry activity can include 'From which perspectives do you, others and society value the inquiry?' and 'Should the inquiry activity proceed or stop?'

## 2.2.2 Pupil interactions with peers

Once pupils acquire a basic understanding of inquiry they need to practice communicating their understanding through social interactions. Their first important social interaction is communication with peers. Teachers can encourage pupil-pupil interactions by applying lesson plans that include group work and classroom dialogue when choosing to implement an inquiry activity. For example, the collaborative controversies scenario created for the SCY project of the European Union (Science Created by You) is a lesson plan template that structures learning around group work and a socio-scientific issue. The scenario was developed for an education research project (see Wasson & Ludvigsen, 2003; Wasson 2007) and was inspired by progressive inquiry learning (Muukkonen et al., 1999) and Kolstø's research on controversies in learning science (Kulstø 2001a, 2001b).

In the collaborative controversies scenario pupils are exposed to an inquiry activity that contains both ethical and science issues. Pupils first individually conceptualise the topic and write down their ideas and viewpoints. Then they work in groups to find pro and con arguments for the controversial issue, as well as write down questions for which the group cannot find answers. After all groups have analysed their arguments the teacher initiates a class wide debate where the groups discuss their questions and present their pro and con arguments. The teacher has the responsibility to frame the learning argument and direct the

discussion towards a summary conclusion. The collaborative controversy scenario is useful for engaging pupils in analysing evidence presented by peers and having groups search actively for a compromise solution. This social interaction is a productive way to begin developing RRI awareness in pupils through inquiry learning. In general, pupil-pupil interactions that raise RRI awareness in the Ark of Inquiry can often be accomplished by supporting teachers in applying lesson plans that incorporate collaborative group work and classroom discussion.

## **2.2. 3 Pupil Interactions with Informal Educators**

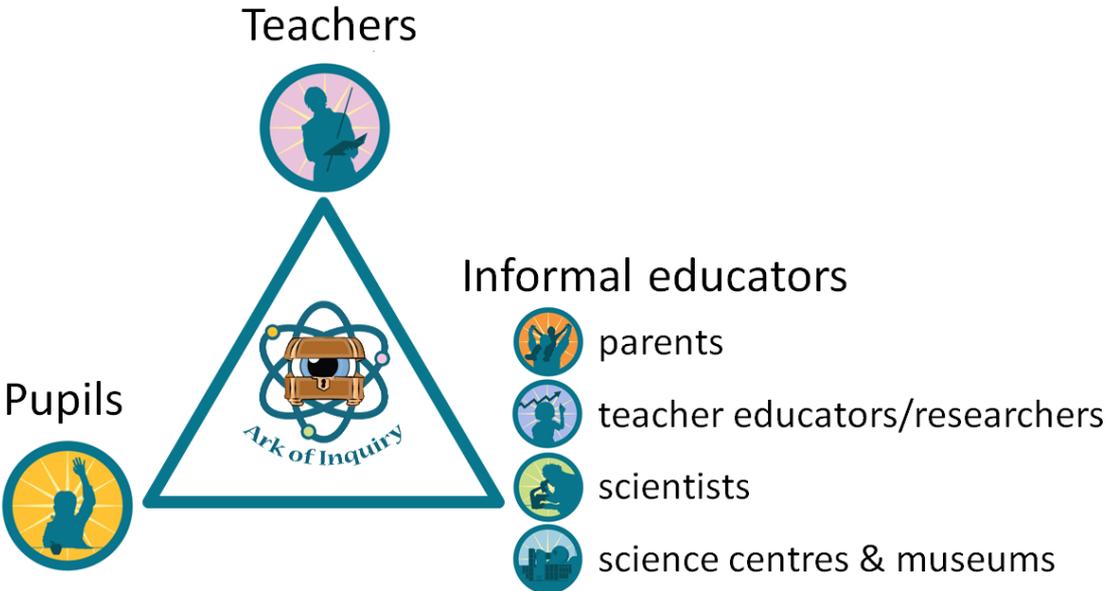
An expanded sense of RRI awareness in the Ark of Inquiry emerges when pupils engage with informal educators. Informal educators are people or situations outside of the formal school setting that can facilitate learning science. Informal learning environments afford unique learning experiences that can stimulate science interest, build learners' scientific knowledge and skill, and help people become comfortable with science in society (National Research Council, 2009). In the Ark of Inquiry project informal educators are more specifically defined as teacher educators/researchers, parents, scientists, science centres and museums. In the Ark of Inquiry interaction with informal educators advances pupils' RRI awareness by exposing them to the perspectives and practices of important societal actors involved in the research and innovation process. After communicating and discussing with peers, interaction with external informal educators extends pupils' scope of RRI awareness, widening their audience to include other ages, expertise and perspectives than present in their own classroom environments.

Teachers are very important facilitators for encouraging interactions between pupils and informal educators. Weiland and Akerson (2013) provide some suggestions for how teachers can best serve as intermediaries between pupils and informal educators. The authors describe a relationship between a primary school teacher and an informal science educator who came to visit the teachers' classroom as a guest speaker. Weiland and Akerson point out that a teacher's role in this situation should be to manage the classroom, make connections to the curricula and clarify concepts. It is important to realise that teachers best understand their pupils' prior knowledge and experiences, and should therefore facilitate effective dialogue between pupils and informal educators by clarifying ideas pupils may not have understood.

In the case of interactions between pupils and informal educators that occur outside of the classroom (e.g., a pupil works on a research project together with an informal educator) the teacher still has an important role to play. The teacher should ensure that pupils meet project deadlines, conduct the inquiry themselves (as much as possible), and communicate regularly with their informal educator. For primary school children an informal educator is often a parent, whereas for secondary school pupils the informal educator is likely to be a scientist or university researcher.

Parents are important informal educators in the Ark of Inquiry project, especially for the younger pupils who will engage in inquiry activities. Support materials provide instructions to parents on how they can register their child on the Ark of Inquiry platform, how the platform assesses children’s inquiry skills and how to find appropriate inquiry activities. In terms of supporting pupils, the support materials offer guidelines for posing questions, searching for evidence and finding relevant equipment for experimentation. In general, parents will find in the support materials answers concerning their expected role in the project and how to scaffold their child’s/children’s inquiry activities at home.

Overall, it is through multi-faceted interactions between teachers, pupils and informal educators that the awareness of young people on the subject of Responsible Research and Innovation in the Ark of Inquiry is expected to build up. Figure 1 illustrates this important three-actor relationship.



**Figure 1.** RRI raised through multi-faceted interactions among teachers, pupils and informal educators.

## **2.3 Support for the Ark of Inquiry Platform**

The Ark of Inquiry platform is the web-based portal through which inquiry activities, learning resources and the evaluation and award systems are made available to pupils and educators. Support is needed to ensure that the platform functions effectively. Deliverables D1.1, D1.2, D1.3, D2.1 and D2.2 provided detailed descriptions of critical elements that form the foundation of the Ark of Inquiry platform. In this section we summarize how these elements support learners in order for them to engage in inquiry activities, start and complete the envisaged activities, become motivated to take challenges set by higher-level activities, and expand their awareness of RRI. This section splits into two parts. First we discuss support in the evaluation and award systems and then we discuss support from pedagogical scenarios. These forms of support are mainly implicit since the evaluation and award system as well as the pedagogical scenarios implicitly scaffold the process of inquiry learning.

### **2.3.1 Evaluation and Award Systems**

Pupils in the Ark of Inquiry will be assessed on their level of inquiry skills and awareness of RRI. The evaluation system described in deliverable D1.2 provides instruments and procedures for performing this assessment. In deliverable D1.3 the instruments and procedures of the award system that aims at motivating inquiry and celebrating success and RRI excellence are described. Both the evaluation and award systems are based on three design principles: personalized learning, self-regulation, and a community of learners.

The evaluation and award systems in the Ark of Inquiry platform support pupils in various ways. Central to the evaluation system is that the platform provides materials that explain how to build a personal pupil portfolio. A portfolio is a collection of assessment products that show what a pupil has been doing, how he or she has progressed and what the results so far have been. Materials for building a portfolio include self-assessment forms, collection of samples of inquiry products, dialogue reports and peer feedback. Self-regulation is central to both the evaluation and award system because the pupil self-assesses and self-nominates his or her performances before discussing those with peers and their teachers.

Important to both the evaluation and award systems is a community of learning. Through this community pupils can support their peers by sharing their knowledge and experiences, as well as providing constructive feedback on the work of others. In the Ark of Inquiry this communication is envisioned to occur primarily within classrooms and through social media technologies on the Internet. In order to support this type of communication online forums can be used (e.g., Google Groups). For pupils motivated by public recognition, the Ark of Inquiry award system encompasses a Hall of Fame, which lists the names of pupils with the most outstanding performances in the Ark of Inquiry.

## 2.3.2 Pedagogical Inquiry Scenarios

Deliverable D2.1 established a set of selection criteria for including inquiry activities into the Ark of Inquiry. The current collection of inquiry activities has shown that although the chosen activities can satisfy all of the selection criteria at the minimum level, they rarely meet every aspect of the selection criteria at the highest level. It would be advantageous and supportive of wider engagement of pupils in inquiry if the collected inquiry activities could be adapted from their original version to allow for broader contextual use. In effect, it is desirable to be able to adapt and re-use inquiry activities in new contexts (e.g., different age and skill levels). Deliverable D2.2 has in fact developed pedagogical inquiry scenarios to help guide teachers in making these adaptations. These adaptations allow for flexibility in using inquiry activities and ensure wider-ranging implementation of inquiry in various educational contexts.

Deliverable D2.2 identifies pedagogical scenarios that explain how to modify an inquiry activity. Among these scenarios are (1) mapping between inquiry models, (2) adding inquiry phases, (3) changing the proficiency level, (4) improving gender inclusion, and (5) overcoming language barriers. These scenarios guide educators in building on existing inquiry learning materials and implementing these in the best possible way in their own classroom settings. For example, the Ark of Inquiry pedagogical framework describes five inquiry phases through which pupils advance in their inquiry proficiency levels, but not every inquiry activity is structured initially like this. A pedagogical scenario of adding inquiry phases explains how to perform this adaptation.

### 3. Conclusions

This deliverable presented an initial specification of support mechanisms that help engage and motivate teachers and pupils in the Ark of Inquiry. In effect it derives from work in WP1 (Pedagogical framework) and WP2 (Collection of inquiry activities and environments) that structure the foundation for the Ark of Inquiry. These initial support specifications are needed for upcoming work to create supportive communities in WP3 (Supporting community) as well as developing supportive materials in WP4 (Training).

The *Framework for Inquiry Proficiency* developed in deliverable D1.1 established a common reference from which to develop inquiry skills and awareness of Responsible Research and Innovation. In terms of inquiry skills, support is provided to both pupils and teachers during each phase of the inquiry learning cycle. Thus, support ensures that teachers are well-prepared to apply a genuine inquiry learning approach and pupils can retrieve assistance to accomplish tasks that are beyond their ability to complete alone.

An important feature of support systems in Ark of Inquiry is that there are two distinct groups of stakeholders (formal and informal educators) who interact with pupils. The formal educators are teachers whereas the informal educators can range from science centre or museum staff to scientists, teacher educators, and parents. Interaction with informal educators was identified in deliverable D1.1 as a key aspect to developing greater awareness of RRI because it prepares pupils to become active and informed participants in societal discussions with regard to science and technology. In the Ark of Inquiry, support systems for RRI are focused on engaging and motivating the constructive interaction among three key actors: teachers, pupils, and informal educators.

Additional principles for specifying support systems came from work done in deliverables D1.2 (Instruments for evaluating inquiry experiences, skills and societal responsibility), D1.3 (Description of the system of Inquiry Awards that foster responsibility) and D2.2 (Pedagogical inquiry scenarios for re-use of inquiry activities). These deliverables provided support that was discussed in relation to the Ark of Inquiry platform.

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## 5. Appendix 1

**Table 1**

<b>Transformative inquiry skills</b>	<b>Example guidelines for pupils</b>
Problem identification	“Observe, identify similarities and differences.”
Research question formulation	“Research question is a question that contains independent and dependent variables.”
Hypothesis formulation	“Hypothesis is the answer to the research question which is theoretically justified and evaluated by experiment.”
Experiment planning	“You should fix all the variables and conditions which are needed for successful experimentation.”
Carrying out an experiment	“In order to find an answer to your research question, follow the experiment plan.”
Analysis and interpretation of results	“Try to look for patterns in your collected data and consider whether it relates to your research question.”
Drawing conclusions	“Your conclusion must be based on the data you gathered and provide an answer to your research question.”

## 6. Appendix 2

**Table 2**

<b>Regulative inquiry skills</b>	<b>Example guidelines for pupils</b>
Planning	“Now you have to think how to check the correctness of the hypothesis.”
Monitoring	“You should take note while stating your research question.”
Evaluating	“You have to check whether all components of the hypothesis are present and fit with your stated research question.”