Ark of Inquiry: Inquiry Activities for Youth over Europe

Deliverable D2.4

Pedagogical inquiry scenarios for re-use of inquiry activities

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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 disseminating across Europe engaging inquiry activities in Science, Technology, Engineering and Mathematics (STEM) domains.

The current deliverable describes six Pedagogical Scenarios that are designed to help teachers across Europe to evaluate, implement, adapt and reuse inquiry activities in their classrooms in the context of the Ark of Inquiry project. The Pedagogical Scenarios, listed below, are generic, meaning they can be applied globally in various educational contexts outside and beyond the Ark of Inquiry project.

1. Introduction to the concept of inquiry learning and the Ark of Inquiry learning model
2. Promoting awareness of Responsible Research and Innovation (RRI)
3. Empowering girls in science
4. Adjusting the inquiry proficiency level
5. Adding or improving inquiry phases
6. Overcoming language and sociocultural barriers

The need for the scenarios stems from the fact that the focus within the Ark of Inquiry project is on pre-existing inquiry principles that are fundamental and unique to the project, meaning that most of the existing inquiry activities might not optimally fit into the framework of Ark of Inquiry. In this respect, the pedagogical scenarios can be considered as means (or pedagogical tools) to bridge the gap between the existing activities and the requirements for use in the Ark of Inquiry. The underlying idea of the Pedagogical Scenarios is that teachers should be supported in taking ownership of the activities and in developing professional competencies in order for them to be able to adapt activities to their (unique) educational goals. The pedagogical scenarios not only assist those teachers who seek to adapt inquiry activities, but can shape attitudes of those who might not have (yet) considered the approach of tailoring the activities to their pupils' needs.

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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 Science, Technology, Engineering and Mathematics (STEM) domains.

The current deliverable describes six Pedagogical Scenarios (outlined below) that are designed to help teachers across Europe to evaluate, implement, adapt and reuse inquiry activities in their classrooms in the context of the Ark of Inquiry project. The need for the scenarios stems from the fact that the focus within the Ark of Inquiry project is on pre-existing inquiry activities, which have not been designed according to the principles that are fundamental and unique to the project, meaning that most of the existing activities might not optimally fit into the context of Ark of Inquiry. This was anticipated in the DoW and confirmed in the review of inquiry activities for the deliverable D2.3 (Population of the Ark of Inquiry platform for piloting) and during the piloting, which both identified a need for adjustments in many potentially interesting activities before they could be used effectively in the classrooms across Europe within the framework of the Ark of Inquiry. In this respect, the Pedagogical Scenarios can be considered as means (or pedagogical tools) to bridge the gap between existing activities and the requirements for use in the Ark of Inquiry. The underlying idea of the Pedagogical Scenarios is that teachers should be supported in taking ownership of the activities and in developing professional competencies in order for them to be able to adapt activities to their (unique) educational goals.

Outline of the six Pedagogical Scenarios:

1. Introduction to the concept of inquiry learning and the Ark of Inquiry learning model
2. Promoting awareness of Responsible Research and Innovation (RRI)
3. Empowering girls in science
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Pedagogical scenarios can also save possibly applicable inquiry activities in the Ark of Inquiry Platform from being discarded by teachers. Discarding happens due to the fact that when searching for inquiry activities, many practising teachers already have drafts of learning environments or pedagogical aims (or both) in mind. This means that in many cases, if an inquiry activity will not exactly match teachers' preliminary expectations, they simply continue looking for another without considering modifications. Additionally, in many countries, there is a certain population of teachers who will not innovate in their teaching: rather, they are expecting cookbook-recipes for teaching. The pedagogical scenarios aim to assist not only those who seek to adapt inquiry activities, but also shape the attitudes of those who have not (yet) considered the approach of tailoring the activities to their pupils' needs.

The pedagogical scenarios described in this document are generic, meaning that each scenario can be implemented in relation to any inquiry activity inside and outside of Ark of Inquiry where the scenario applies to. There are three advantages of using generic scenarios instead of specific (activity level) scenarios. Firstly, generic scenarios are less resource intensive compared to specific scenarios; it is clear that the project does not have resources to provide specific scenarios for individual activities. However, the latter can be achieved via another mechanism, namely asking teachers to share their amended activity plans for activities that they select and use in their classrooms. Secondly, generic scenarios allow flexible and widespread use of the existing activities in the Ark of Inquiry, making it easier to adapt individual activities to various classrooms (e.g., match the level of challenge offered by the inquiry activity to the pupil's ability), irrespective of age and different skill levels, formal/informal learning situations, and different country contexts. Thirdly, generic scenarios put the teacher into the role of an active designer of learning situations instead of being a passive content consumer. The role of a designer will endorse the feeling of teachers' ownership, autonomy and commitment to the inquiry activities (Rutten, 2014), which can be considered important for achieving large-scale and sustainable uptake of the Ark of Inquiry across the schools in Europe.

The choice of the scenarios is based on the aims of the project as formulated in the DoW and work conducted particularly in work packages 1, 2 and 4. Deliverable D2.2 (Pedagogical inquiry scenarios for re-use of inquiry activities - initial) presented the initial set of five pedagogical scenarios. These five scenarios are included in the present deliverable, but they have been re-written based on the feedback from project partners and teachers before and during the piloting that took place at the end of 2015. The deliverable includes one completely new pedagogical scenario on Responsible Research and Innovation (RRI) to account for and reflect upon the European Commission's vision to prepare pupils to take responsibility in the research and innovation processes as researchers or citizens in the future. The deliverable also includes examples illustrating how the scenarios can be implemented in practice. The examples can be considered as (additional) meta-scenarios, as they illustrate how individual inquiry activities can be first analysed and evaluated from the viewpoint of the individual scenario and then, based on the analysis and situational needs, adapted and improved from each perspective. The examples also show how decisions in relation to one scenario might facilitate achieving goals in one of the other scenarios and as such they illustrate the value of going through all scenarios while reviewing an activity.

In summary, the pedagogical scenarios are designed to enhance the uptake and use of inquiry activities across schools in Europe in the context of the Ark of Inquiry project. Because of their generic nature, the pedagogical scenarios can be applied globally in various educational contexts outside and beyond the Ark of Inquiry project.

2. Pedagogical scenarios

It is common that learning materials need modifications and additions before they can be used in the classroom. Thus, teachers may find it necessary to adapt existing inquiry activities to the local needs and circumstances. There may also be teachers who do not consider adaptation as an option, and they may ignore potentially applicable and productive inquiry activities. For these reasons, we have developed the following six pedagogical scenarios that guide teachers to evaluate and redesign inquiry activities from six perspectives and overall consider adaptation as a viable option to use a variety of inquiry activities in their classrooms.

1. Introduction to the concept of inquiry learning and the Ark of Inquiry learning model
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The pedagogical scenarios are built around the vision of a future classroom where the focus is on authentic, engaging and empowering learning tasks and problems that expand beyond the school environment and involve various societal actors and where the focus is as much (or even more) on the learning process and experience as it is on content and the final outcome.

Scenario 1: Introduction to the concept of inquiry learning and the Ark of Inquiry learning model

This scenario supports teachers in order for them to familiarize themselves both with the concept of inquiry learning and the Ark of Inquiry learning model. It also encourages them to compare their own inquiry approach (if they are using a different inquiry learning model) to that of Ark of Inquiry and teach pupils the Ark of Inquiry learning model.

- If you are new in inquiry learning, you should familiarize yourself both with the concept of inquiry learning and the Ark of Inquiry learning model.
- There are various inquiry models. If you are using a different inquiry learning model, you should compare your own inquiry approach to that of Ark of Inquiry. Identify where the approaches overlap and/or differ.
- At one point, it is also important to inform pupils about the inquiry model used, as this knowledge will help them to understand the inquiry process and monitor their progress in different inquiry phases. Younger or inexperienced learners might not be introduced to the full model immediately, but it might still be a good idea to have the inquiry model visible during an inquiry session to make learners already familiar with the cyclic nature of inquiry.

Scientific inquiry and inquiry learning.

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work. Inquiry also refers to the activities of learners in which they develop knowledge and understanding of scientific ideas as well as understanding of how scientists study the natural world. More specifically, inquiry is an approach to learning that involves a process of exploring the natural or material world, which in turn leads to asking questions, making discoveries and rigorously testing those discoveries in the search for new understanding. Inquiry, in the context of science education, should mirror as closely as possible the enterprise of doing real science (National Science Foundation, 2000).

Ark of Inquiry learning model (Pedaste et al., 2015).

There is a variety of different inquiry models, and as a matter of fact, the model used in the Ark of Inquiry is actually derived from a collection of models. It is based on the Pedaste et al. (2015) model and consists of five distinct inquiry phases: Orientation, Conceptualization, Investigation, Conclusion, and Discussion (see Figure 1). These five phases are meant to provide pupils a good and comprehensive learning experience in a process that resembles real scientific inquiry.

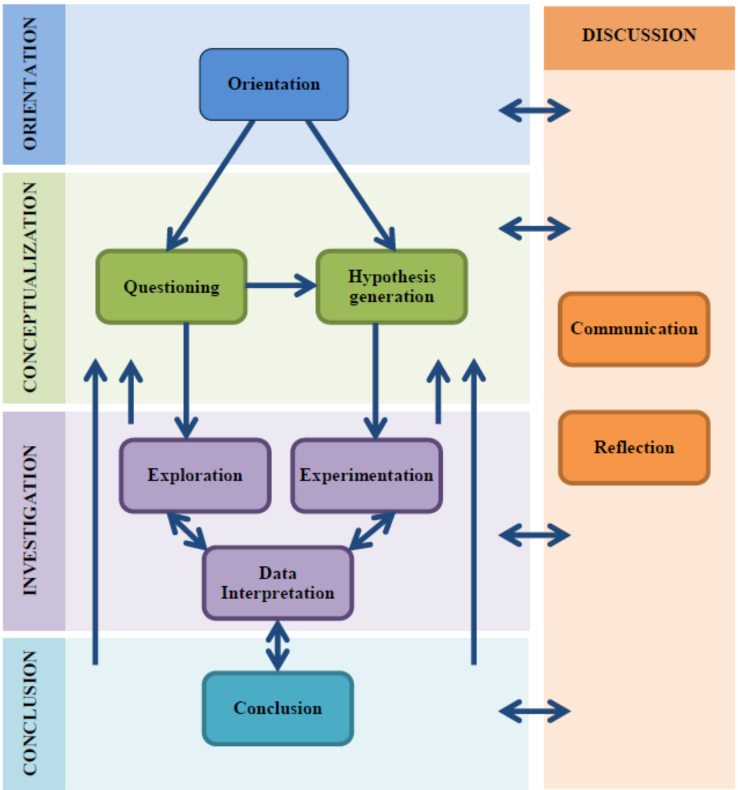


Figure 1. Pedaste et al. (2015) inquiry learning model.

Orientation phase: Inquiry begins with this phase. The main aim of this phase is to introduce the topic, stimulate curiosity about the topic and provide pupils with opportunities for defining a problem statement.

Conceptualization phase: In this phase research questions and/or hypotheses are stated. The phase includes two sub-phases: Questioning or Hypothesis Generation. The difference between the sub-phases relates to the familiarity of pupils with the theory that underlies the topic under study. Pupils who are familiar with the topic can start immediately from the Hypothesis Generation sub-phase; they must have enough background information to formulate a specific hypothesis. Pupils having little to no background should start with the Questioning sub-phase (which subsequently guides them to the Investigation phase via the Exploration and Data Interpretation sub-phases). After acquiring experience with the topic pupils can return and select the Hypothesis Generation sub-phase. Hypothesis Generation is an important phase because it leads to the Experimentation sub-phase, where the hypotheses are tested.

Investigation phase: The Investigation phase is based mostly on hands-on activities. It is a process of gathering empirical evidence to answer the research question or verify hypotheses. For example, pupils work in groups in a science laboratory to find evidence for the problem statement defined in the Conceptualization phase. The Investigation phase includes three sub-phases: Exploration, Experimentation, and Data Interpretation.

Conclusion phase: In this phase, research findings from the Investigation phase are reported and justified by the results of the investigation.

Discussion phase: This phase of inquiry is directly connected to all the other phases. It consists of communicating partial or completed outcomes as well as reflective processes to regulate the learning process. The Discussion phase includes two sub-phases: Communication and Reflection. The Communication sub-phase generates support for scientific research or study or serves the purpose of informing decision-making, including political and ethical thinking. The Reflection sub-phase aims to meaningfully raise pupils' skills in developing creative, scientific problem-solving and socio-scientific decision-making abilities.

Mapping different inquiry models.

In practice, there is a variety of different inquiry models. A popular model is that of Bybee´s 5E-model (Bybee et al., 2006), which consists of five inquiry phases: Engagement, Exploration, Explanation, Elaboration, and Evaluation. Another well-known model is that of White and Frederiksen (1998), which also emphasizes five inquiry phases, but names them as Question, Predict, Experiment, Model, and Apply . Differences between White and Frederiksen´s and Bybee´s models appear in the approach: the first two phases (Engagement and Exploration) in Bybee´s model are describing the inductive approach (data-driven/empirical), whereas the two first stages of White and Frederiksen´s model are concentrating on the deductive approach (hypothesis/theory thriven) (Pedaste et al., 2015).

Table 1. Mapping Bybee´s and White and Frederiksen´s model onto Ark of Inquiry 5-phase learning model.

Inquiry phases in Ark of Inquiry 5-phase learning model	**Inquiry phases in Bybee´s model**	**Inquiry phases in White and Frederiksen´s model**
Orientation	Engagement	-
Conceptualization	Engagement	Question and Predict
Investigation	Exploration	Experiment and Model
Conclusion	Explanation and Evaluation	Model
Discussion	Explanation and Elaboration	-

Although the models described above (Ark of Inquiry's, Bybee's, and White and Frederiksen's inquiry models) are distinct inquiry models, they exhibit a high degree of correspondence and similarity with each other in regard to their inquiry phases. Table 1 shows how Bybee's and White and Frederiksen's models can be mapped onto the Ark of Inquiry learning model in regard to the inquiry phases (Table 1). As can be seen from the table, the inquiry phases described in the Ark of Inquiry learning model mostly coincide with the phases in Bybee's model, with the main differences lying upon the names of phases and some phases in one being a combination of two phases in the other. And, the other way around, White and Frederiksen's model consists of three phases which can be directly mapped onto three phases of inquiry process as described in the framework of Ark of Inquiry (Conceptualization, Investigation, and Conclusion), but is lacking the Orientation and Discussion phases.

Scenario 2: Promoting awareness of Responsible Research and Innovation (RRI)

This scenario supports teachers to familiarize themselves with the concept of RRI and gives them ideas how to incorporate elements that foster awareness of RRI into inquiry activities.

Responsible Research and Innovation (RRI) is a central theme in the European Union vision. RRI initiatives in science education aim to boost interest of children and youth in STEM and to prepare them to take responsibility in the research and innovation processes as researchers or citizens in the future. While formal science education aims at effectivity and efficiency of science education in school in the short run, RRI aims to foster science use outside of formal education in the long run and connect science education to globally recognized issues (e.g., the following seven Grand Challenges identified by the EU: sustainable agriculture, climate action and resource efficiency, global poverty, inclusive and secure societies, health and well-being, sustainable transport, and clean energy). The aim of a curriculum oriented toward socio-political action is to create a generation of scientifically and politically literate citizens able to solve current social and environmental problems. This requires a greater consideration of the interactions among science, technology and society in the school science curriculum in order to raise awareness of RRI and to meet the needs, interests and aspirations of young citizens at the same time.

For this purpose, the Ark of Inquiry project advocates emphasis on three aspects that can help to foster pupils' awareness of RRI and in the longer run prepare them to take part in RRI: **reflection, communication** and **discussion**.

The purpose of reflection is that pupils should start to (individually) think through the relevance, consequences and ethics of research and research outcomes while pursuing inquiry activities. Reflection will help pupils develop their own understanding and personal views on the issues they are dealing with. Teachers can support this process by helping learners to recognize the societal and environmental impact of scientific and technological change. This will raise pupils' awareness of the implications and ethics of science and its multi-dimensionality (e.g., economic or political power influencing decision-making; conflicting interests and benefits), which is also important when it comes to communication.

The purpose of **communication** is that pupils present and explain complex themes and problems. However, presenting and explaining complex real world issues is neither a simple nor a superficial task. On the contrary, as already in its simplest form (communicating one's own understanding and personal view) it requires taking the audience (e.g., peers, teacher) into account. It becomes even more challenging when pupils go beyond their own understanding and personal views and try to present and explain multiple perspectives on the issue. Or, in other words, that in reality there are always different stakeholders and societal actors involved and that communication should take that notion into account (by, e.g., incorporating different perspectives, different versions targeting different audiences).

This means that pupils should not only understand that there are various angles to a problem but also be able to formulate their own view on the issue in relation to alternative views. With respect to reflection, this also means taking reflection from the personal perspective to reflection on multiple perspectives. This goes beyond traditional textbooks and heads toward a more active thinking (Hodson, 2003).

Discussion means (inter)acting with an audience (e.g., other stakeholders; and may involve changing one's own position), as well as preparing for concrete action[1]. For this to be achieved it is important that pupils are aware of the implications and ethical dimensions of science and that they have established their own values and opinions on the issue based on arguments and evidence. This is because they need to be able to identify the different mechanisms that influence decision-making and to question problems and proposed solutions from different angles in discussions with other stakeholders. It is also important that pupils learn to take responsible action (which may well include compromising). It is not enough that they learn that science and technology are influenced by socio-political and economic forces; in the end they should move towards active participation in these processes. Pupils should be able to establish their own position, formulate what kind of action is suitable and be ready to engage in discussions with other stakeholders. The aim of the whole learning process through reflection, communication and discussion processes is to enhance the skills and competences that will enable pupils to make judgments and decisions and take informed action (including taking part in RRI initiatives).

Since RRI is a relatively new topic, not many inquiry activities are designed with these views explicitly in mind. However, in some cases some of these notions will be implicitly present, and in other cases there is the possibility to add elements to an activity (or reemphasize the existing elements) in order to raise pupils' awareness of RRI. In any case, following the assessment framework of the Ark of Inquiry (see deliverable 1.6), adding emphasis to reflection, communication and discussion should raise RRI awareness among pupils. Some practical ideas on how to incorporate RRI in an activity are the following:

[1]Action is conceived broadly in this context (in some sense discussion itself could already be seen as action), and might refer to making public statements and writing letters, working on projects, taking part in committees, becoming active in organizations, changing one's own behaviors, etc.

REFLECTION | **COMMUNICATION** | **DISCUSSION**

- Once a teacher identifies a task/selects an inquiry activity, a first step towards RRI is to contextualize the problem from an RRI perspective or, even better, ask the pupils to try to contextualize the problem. Teaching science in socially and personally relevant contexts not only enhances pupils' motivation compared to abstract, de-contextualized approaches, but also increases opportunities for meaningful reflection, communication and discussion outcomes.

  Explicitly have pupils identify the variety of stakeholders who share responsibility for the topic under discussion and have them reflect on potential discrepancies.

- After the learners have conceptualized the problem, they should try to find multiple solutions and review these from different perspectives whenever possible.
- In their conclusions pupils should argue about the consequences of each of the proposed solutions based on evidence and in relation to the audience they are addressing.
- At the next stage it is important that pupils share their conclusions and proposals within their school context. Apart from gaining presentation skills, the aim of discussing with groups of people is that pupils are given the chance to question a problem and different solutions proposed from multiple perspectives. This will help to make them aware that transparency of their inquiry results is an important part of the process. At the same time, they will realize the value of feedback from others. All the aforementioned is essential for pupils to be able to make informed decisions about whether action is needed and also to take action.
- The last step would be preparing pupils for taking action. Having them share the results of their inquiry with a wider audience (e.g., stakeholders, researchers, etc.) or giving them the chance to discuss with various societal actors. These kinds of things could not only help pupils realize that there is a variety of perspectives on each problem, but also that they can gain from the exchange of viewpoints with others and that informed discussions are vital components in RRI.

Scenario 3: Empowering girls in science

Over the past years, research has documented a consistent decline in pupils' interest in science and science careers. This holds particularly in the case of girls. One of the goals of the Ark of Inquiry (and EU) is to make science more attractive for women in order to attract more women to science and science careers. **This scenario describes how inquiry activities in themselves may play a role in engaging girls in science and boost their interest and what kind of actions teachers could consider taking in order to contribute to girls' interest in science.** Though this scenario focuses on empowering girls in science, the global aim is to promote gender inclusive science education. Consequently, the following recommendations and examples illustrate the ways to empower girls in science without negatively affecting boys.

Learner-centred active learning environments

It has been found that teaching/learning methods may play a role in increasing girls' interest in science. Inquiry learning that emphasizes learner-centred learning has provided positive results related to female pupils' interest across a broad array of topics in STEM. In Finnish pilots, for instance, inquiry topics ranged, e.g., from electricity to states of matter to recycling. Independent of gender, a majority of learners reported high levels of interest throughout all the activities.

Use of RRI elements in inquiry activities

Learning contexts that include RRI elements (see RRI section above) may also play a role in increasing girls' interest in science For instance, the outcomes of the MSOSW project (Middle Schoolers Out to Save the World) indicated that girls' attitudes towards science became generally more positive and even approximately equal to boys' attitudes during the project year. The MSOSW project included hands-on activities to guide pupils to solve real-world problems, combining both learner-centred learning environments and an everyday-life problem context. They used, for instance, energy monitoring equipment to monitor and audit power consumption by consumer electronic devices in their homes and communities. This way they tried to reduce the greenhouse gas emissions contributing to global warming. Pupils shared their results with other middle school pupils from across the U.S. (Knezek, Christensen, Tyler-Wood, & Periathiruvadi, 2013).

Avoiding stereotypes

To reach all pupils in a classroom it is important to avoid stereotypes in science teaching. This notion concerns both science itself and the pupils, and relates to textbooks, problem sets, language used by the teacher, or how girls and boys are addressed in the classroom (e.g., equal time should be given to boys and girls to ask questions or reply to them). The influence of stereotypes about science is still decisive in the career choices of many girls (and boys), and in particular in girls' decisions not to embark on a scientific career. They often have a restricted conception of what science is (e.g., disregarding the multidisciplinary nature of contemporary science and increasing array of emerging applied science fields), therefore not considering science studies that could lead to careers in (even non-science) fields that actually do match their future occupational interest. Compared with their male classmates with similar grades in science subjects, girls also often have lower self-esteem concerning their scientific ability as a direct result of stereotypes ("girls can't do science"). Most are not aware of this, though, and as a result underestimate their ability to the extent that they believe science is too difficult for them. As a result, they often choose an alternative, non-scientific career path. Many adults, too, are unaware of their stereotypes regarding science. Many of us, for instance, automatically and subconsciously associate professions like architecture or engineering with male practitioners, and in our mind's eye "see" nurses and secretaries as women. These implicit associations can be very persistent and reflect in the way we interact with both science and pupils in the classroom. It is important, therefore, that we raise our own awareness and reflect upon our stereotypical perceptions of science, science domains, and what it means to be a scientist so that we can address them and hence change the way we act. As an example of breaking stereotypes, consider the above findings from Finnish pilots: stereotypically, electricity could be considered as a male topic, whereas the findings show that boys and girls performed equally well on the activity and both considered the activity as highly engaging (see Example 1, later in this document, for more details on the activity and the outcomes). While this is an example of a single activity, it might also be important to consider diversity as a dimension for choosing inquiry activities in terms of domains but also in terms of emphases on different phases of the inquiry (e.g., to show that contemporary science is a social rather than a solitary activity).

Use of female role models

Use of female role models and mentors to guide girls' learning in science has also produced positive outcomes. Increasing the diversity of role models can be considered as a second example of working against stereotypes and promoting gender inclusive science education. In the study by Tyler-Wood, Ellison, Lim, & Periathiruvadi (2012) female mentoring was combined with authentic learning experiences in environmental science for 4th and 5th graders. The results indicated that the participants' knowledge of science improved significantly. The researchers also examined the long-term impact of the programme, which showed that at the age of entering college the pupils still showed more positive attitude towards STEM careers than their control group peers. Female scientists as role models and mentors were also used in a series of science and math workshops called "Girls in Engineering, Mathematics, and Science (GEMS)". The workshops offered hands-on activities to middle-school female pupils on weekends. The survey data showed that participant interest in science and math increased by an average of 35 per cent after attending a GEMS event (Dubetz & Wilson, 2013). The notion of mentors and role models might be addressed both within the Ark of Inquiry project itself (through communities) and locally (through local mentors and role models).

Scenario 4: Adjusting the proficiency level

It is important to acknowledge that learners (even inside the same classroom) differ in terms of how competent they are in inquiry learning (e.g., evaluate scientific evidence and explanations). In the Ark of Inquiry project inquiry activities are divided into three different proficiency levels – novice, basic and advanced – depending on the amount of challenge they present to the learner (see Appendix A and Deliverable D1.1., p. 13-18 for more details on the proficiency levels). **This scenario helps teachers to adjust inquiry activities to fit the needs and abilities of learners.** Changing the proficiency level of an activity can be done by changing the amount of structure and/or the amount of support (either increasing or decreasing) that the learner gets during the activity. Thus, check the following:

- Is the activity suitably challenging for your pupils? Comparing the demands of the activity with the skills and abilities of your pupils helps you to decide if you need to make some adjustments. If the activity seems suitably challenging, then no changes are needed.
- In case the inquiry activity seems too difficult for your pupils you might want to lower the proficiency level. This can be done by giving the pupils more guidance during the activity and increasing the structure of the inquiry task.
- If the inquiry activity seems too easy for your pupils it might be a good idea to increase the proficiency level. By reducing the structure of the inquiry process and limiting the amount of guidance you can make the activity more challenging and this way better match the skills of your pupils (see examples in this document and Deliverable D2.2, p. 13-23, for more details on how to change proficiency levels).

Scenario 5: Adding or improving inquiry phases

The Ark of Inquiry inquiry model consists of five distinct inquiry phases as described in the Scenario 1 above. Sometimes activities may lack one or more inquiry phases or some phases might not be as good and comprehensive as others. This is why some activities may benefit from adding or amending phases of the inquiry activities. **This scenario helps teachers to add or improve inquiry phases step by step:**

When selecting inquiry activities, it is recommended to inspect whether the activity includes all phases and evaluate the quality of existing phases.

- Does the activity have all the phases? What is the quality of the existing phases? Is there room for improvement or changes that would make the activity better fit your purposes (e.g., match your own inquiry approach)?
- If one or more phases are missing in the inquiry activity it is recommended that missing phases are added (see examples later in this document). This is because inquiry activities that include all five inquiry phases are more likely to provide a good and comprehensive learning experience for your pupils.
- If the activity has all the inquiry phases, but some of them lack quality, you should improve them in order to make the activity more complete and attractive. Especially at the beginning of the activity (Orientation phase) it would be important to engage pupils and stimulate their interest. Also at the end (Discussion phase) stimulating pupils' reflection on the consequences based on their findings may benefit from changes to the inquiry phases (see the examples later and Deliverable D2.2, p. 24-29).

Scenario 6: Overcoming language and sociocultural barriers

This scenario aims to help teachers to see how to adapt inquiry activities to the local context. This naturally concerns activities that are in a foreign language, but the scenario also highlights the importance of considering inquiry activities from a sociocultural perspective and localizing the activities when needed.

Language barriers.

Activities might be in a different language, but using them might actually require only very little foreign language understanding. Even when real foreign language understanding is needed, there are still some alternatives to consider before rejecting the activity. Below is a list of ideas how to use and adapt foreign language activities.

- Inquiry activities that are in a foreign language can be considered as an opportunity (rather than an obstacle) to integrate content and second language learning. The concept of Content and Language Integrated Learning (CLIL) has gained popularity in different countries over the past years. The advantage of this approach is that the exposure to and use of the second language is increased without the need for allocating extra hours in the curriculum (e.g., teaching science is done in English, and in collaboration between subject and second language teachers). Research related to CLIL shows that increased use of foreign language in these settings increases mastery in the second language without having detrimental effects on the development of the native language. The reason for adopting the CLIL approach is often twofold: it aims at increasing the outcomes of second language education, but often it is also seen as an opportunity to profile their school in order to attract pupils. From this perspective, activities in a second language are not a problem but become an opportunity for fostering a more flexible attitude towards foreign languages by integrating second language learning with content learning in a different subject.
- In case there is a need for translation, consider the following options:
    - If there is a minor language issue, use a glossary.
    - If there is a bigger language issue, but you still like the activity, consider one of the alternatives below:
        - Translate or have pupils translate the activity or parts of it (e.g., online translator machines such as Google Translator, Bing Translator, etc.). This can be done as part of the CLIL approach presented above.
        - If applicable, consider raising the proficiency level of the activity. Activities with higher proficiency levels typically include less text, because the tasks are more open-ended.
        - Contact Scientix (The Community for science education in Europe; www.scientix.eu) and request a translation of the activity. When at least three teachers request translations in one language, Scientix searches for translators.

Sociocultural barriers

All inquiry activities, even those in a native language, should be considered from a sociocultural perspective in order to ensure and enhance task comprehension and engage learners. According to research (e.g., PISA), sociocultural barriers might be a source of alienation from a task or topic or failure for learners. In order for a teacher to be able to introduce “legitimate questions” to pupils (in other words: to expose them to authentic problem situations) it is crucial to critically reflect on the social and local aspects of inquiry activities and consider whether the activity needs adaptation from sociocultural aspects. Sometimes even tiny modifications can act as such. For example, in a landlocked country, a mountain village school might consider their creek and cattle that drink the creek’s water instead of a lake example. Or a river instead of a lake, or a lake instead of sea. These may sound as banal examples, but such details can be decisive points where learners get either motivated by or turn away from an inquiry activity.

Example 1: Electricity Lab

This first example will look at an inquiry activity on electricity. First the description of the activity will be shown, and after that the activity will be first assessed from the perspective of the six scenarios, and then, based on this assessment, some options and ideas for adapting and amending the activity will be presented based on the same scenarios with the underlying idea of improving the fit of the activity in a certain classroom situation.

Description of the activity

Title: Electricity Lab
Domain: Physics
Topic: Electricity, Simple electric circuit
Language: Finnish, English
Language dependency: High
Typical age range: 11–15
Inquiry proficiency level: Novice (A)
Inquiry phases covered: Conceptualization, Investigation, Conclusion

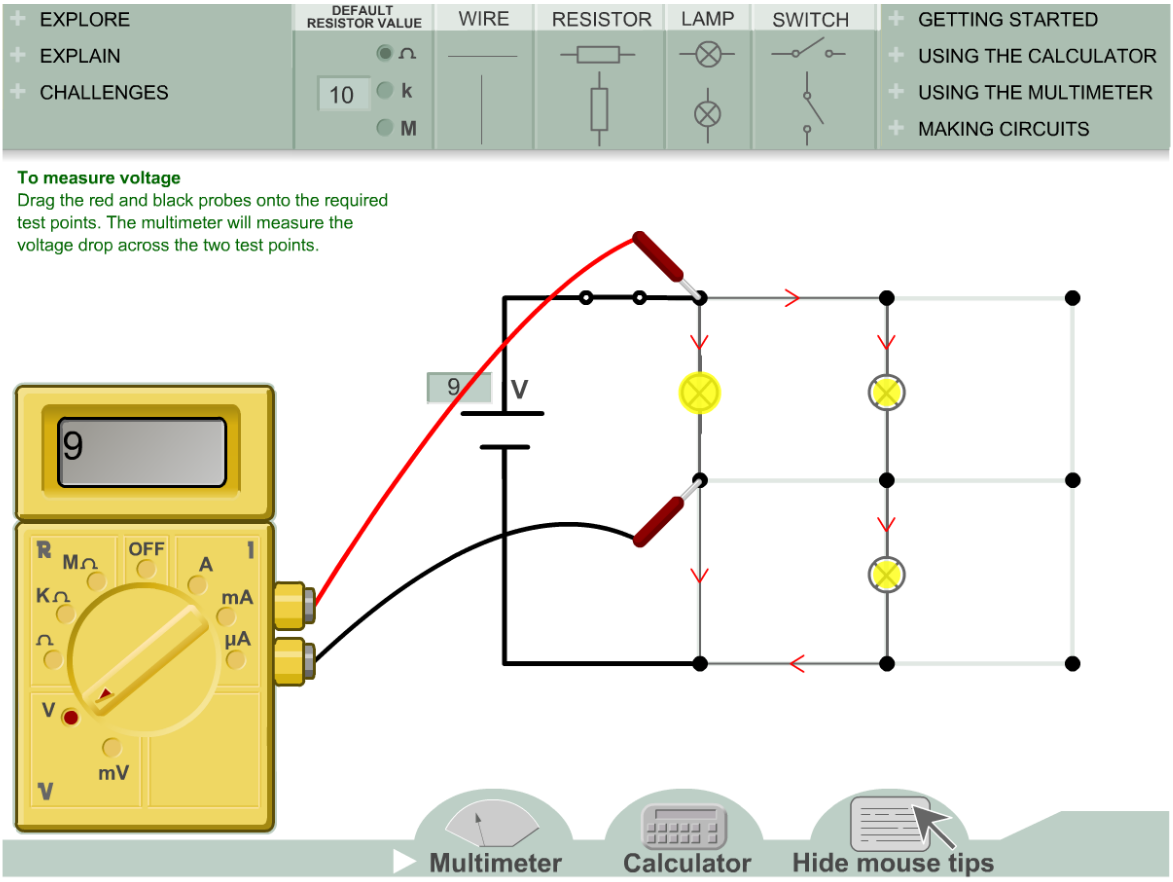
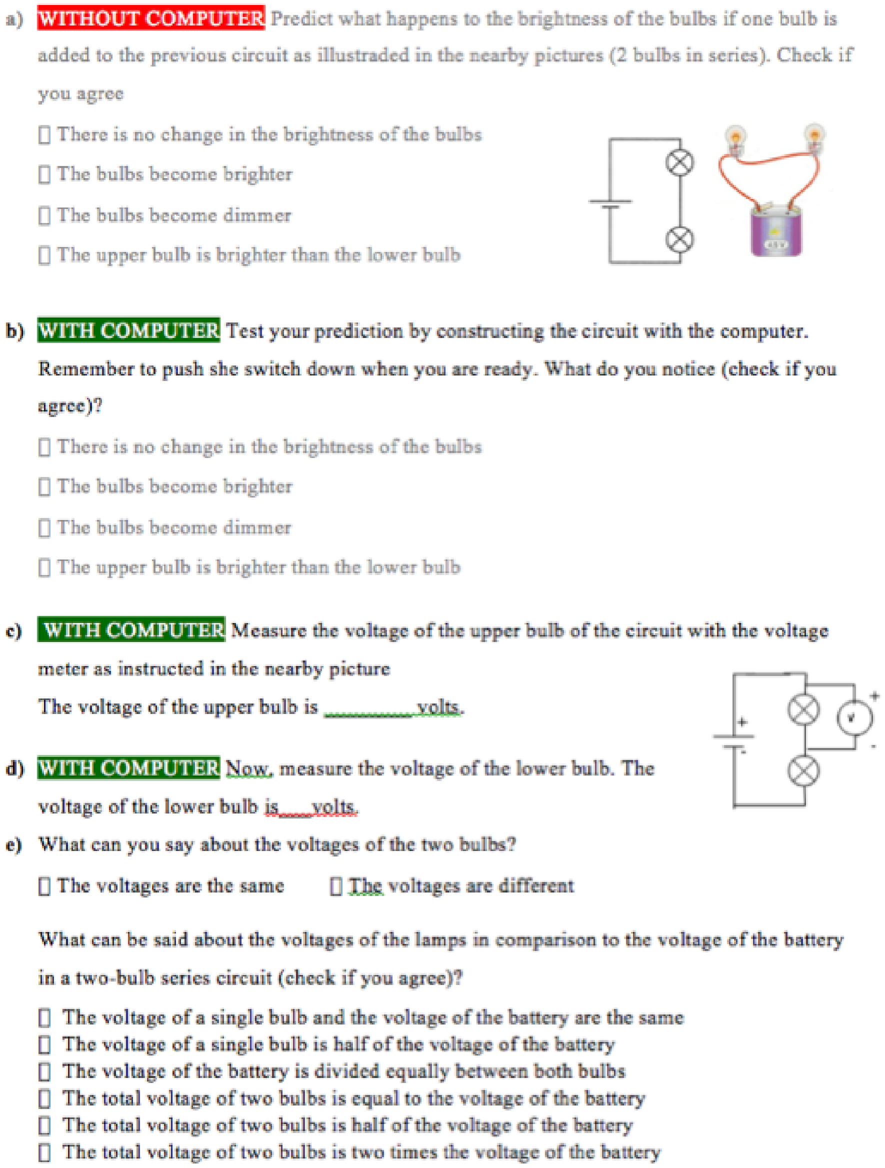


Figure 2. The Electricity Lab is an easy-to-use simulation for constructing simple DC circuits, observing circuit functionalities, and conducting electrical measurement. Every operation is conducted by dragging and clicking with the mouse.

In this inquiry activity learners are guided to explore the basic principles of electric circuits by using a computer-based simulation that models the functioning of electric circuits (Figure 2). The objective of the activity is to discover the basic principles behind the functioning of the electric circuits on a qualitative (relationship between the number of bulbs, the circuit configuration, and the bulb brightness) and quantitative (relationship between the number of circuit components, the circuit configuration, and the voltage across circuit components) level. The inquiry activity consists of a series of worksheets.



a) WITHOUT COMPUTER Predict what happens to the brightness of the bulbs if one bulb is added to the previous circuit as illustraded in the nearby pictures (2 bulbs in series). Check if you agree

☐ There is no change in the brightness of the bulbs
☐ The bulbs become brighter
☐ The bulbs become dimmer
☐ The upper bulb is brighter than the lower bulb

b) WITH COMPUTER Test your prediction by constructing the circuit with the computer. Remember to push she switch down when you are ready. What do you notice (check if you agree)?

☐ There is no change in the brightness of the bulbs
☐ The bulbs become brighter
☐ The bulbs become dimmer
☐ The upper bulb is brighter than the lower bulb

c) WITH COMPUTER Measure the voltage of the upper bulb of the circuit with the voltage meter as instructed in the nearby picture
The voltage of the upper bulb is ________ volts.

d) WITH COMPUTER Now, measure the voltage of the lower bulb. The voltage of the lower bulb is___volts.

e) What can you say about the voltages of the two bulbs?
☐ The voltages are the same ☐ The voltages are different

What can be said about the voltages of the lamps in comparison to the voltage of the battery in a two-bulb series circuit (check if you agree)?

☐ The voltage of a single bulb and the voltage of the battery are the same
☐ The voltage of a single bulb is half of the voltage of the battery
☐ The voltage of the battery is divided equally between both bulbs
☐ The total voltage of two bulbs is equal to the voltage of the battery
☐ The total voltage of two bulbs is half of the voltage of the battery
☐ The total voltage of two bulbs is two times the voltage of the battery

Figure 3. A worksheet example from the original A-level activity

The worksheets instruct learners to construct various circuits and conduct various electrical measurements with the simulation and contain instructional scaffolds that ask the learners to investigate and infer how the changes and differences in circuit configurations affected circuit behaviour. The worksheets gradually become more difficult and divide the inquiry process into small units, creating many small inquiry cycles that each address a specific part of the domain (e.g., open-closed circuits, single-multiple components, series-parallel circuits), and in that sense they can also serve as a way to build in model progression (White & Frederiksen, 1990) in a domain.

In the example shown in Figure 3, the learners are asked to build and investigate a two bulb series circuit (prior to this worksheet, the learners have investigated a single bulb circuit and learned the concept of closed circuit; after this worksheet the learners will continue investigating the properties of series circuits by constructing a three bulb series circuit; after that, they switch to parallel circuits). The worksheet starts with the Conceptualization / Hypothesis Generation phase, where the learners are asked to hypothesize the circuit behaviour prior to using the simulation. In the second step comes the actual Investigation phase, where the learners are guided to set up the circuit, investigate the circuit behaviour (e.g., monitor changes in bulb brightness) and conduct electrical measurements with the voltmeter. The activity ends with a pre-formatted Conclusion phase in which the learner is asked to induce/extract principles from the Investigation phase.

The effectiveness of the Electricity Lab activity, both in terms of learning outcomes and engagement and across various grade levels (from 5th to 8th grade; 10–15 years of age), has been verified in several scientific studies (Jaakkola & Nurmi, 2008; Jaakkola, Nurmi & Veermans, 2011; Jaakkola & Veermans, 2014; Tapola, Veermans & Niemivirta, 2013 ; Tapola, Jaakkola & Niemivirta, 2014). It has been found that this type of activity helps pupils to learn the basic principles of electric circuits and overcome many of their misconceptions. Although using real equipment can complete this type of activity, the use of a computer simulation (or a combination of real equipment and a simulation; Jaakkola & Nurmi, 2008; Zacharia, 2007) is recommended, because the use of the simulation is likely to result in better understanding of the circuits than the use of real equipment alone. The activity has also been rated as highly engaging by both genders.

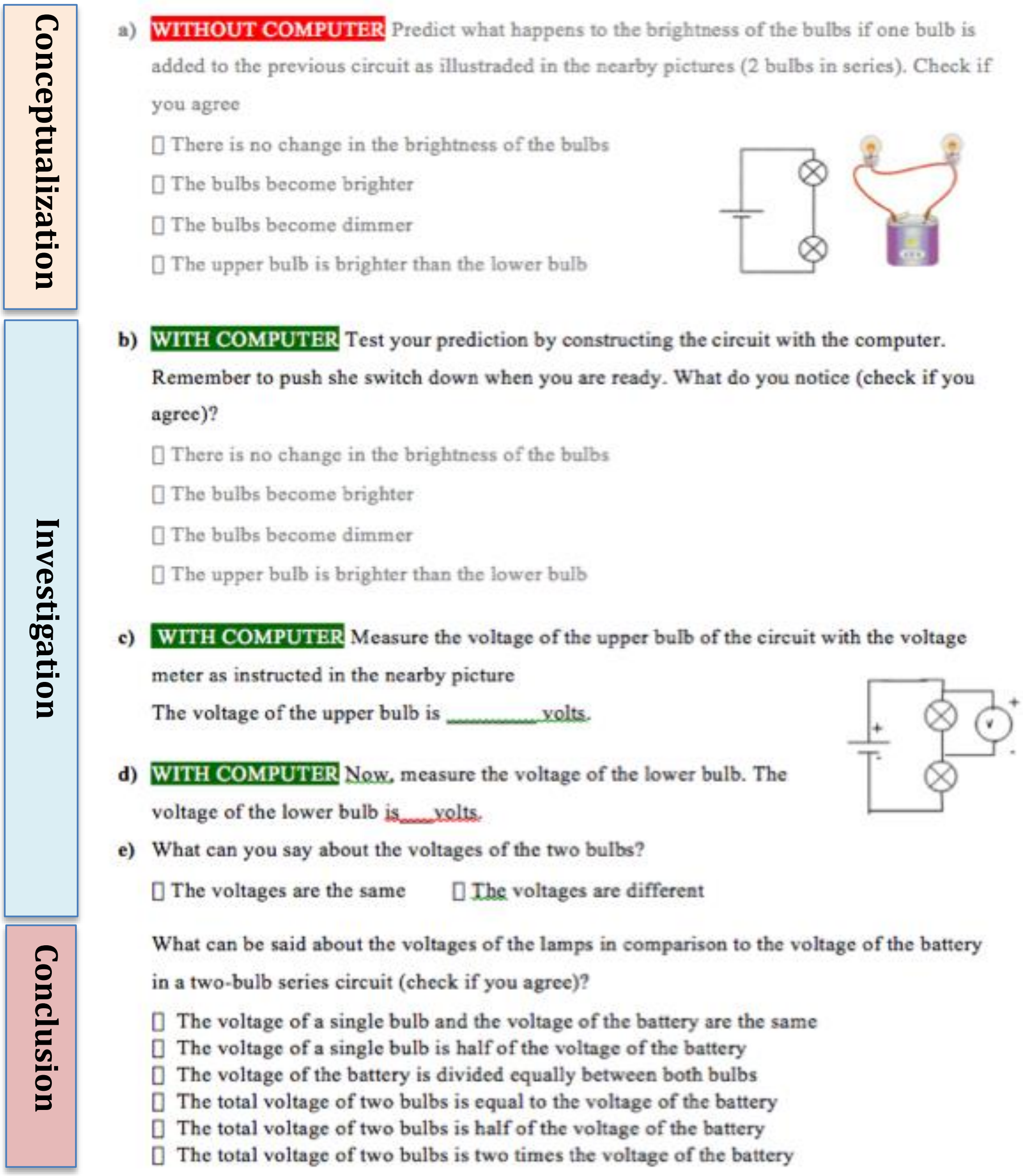
Assessing the activity from the perspective of the six scenarios

Based on studying the description of the activity (preferably, of course, based on the complete activity) the activity will be reviewed from the perspective of each of the six scenarios. The outcome of this assessment forms a basis for considering adaptations and amendments of the activity in order to make it fit better in a particular classroom environment.

Scenario 1: Introduction to the concept of inquiry learning and Ark of Inquiry learning model

Inquiry learning is a process that is often complicated for learners (e.g., Veermans, van Joolingen & de Jong, 2006), and dividing the process into phases can make it more easily explained and understood, especially when learners are not very proficient yet. As such it is also of value to look at activities from the perspective of a framework to see how an activity is structured as well as if and how phases are covered because it will provide important pointers for making changes to the activity based on one of the other scenarios. As such the first scenario in a way provides an initial assessment of the activity against the Ark of Inquiry learning model.

With regard to the Electricity activity, the first thing that can be noted is that it has not been explicitly designed and structured according to the Ark of Inquiry Project Inquiry Model. It does not have explicit references to the phases as they are mentioned in the Ark of Inquiry learning model, so if the goal is to introduce this model to pupils and make pupils familiar with the ideas behind the model the phases should be made more explicit and references to the phases should be added.



a) WITHOUT COMPUTER Predict what happens to the brightness of the bulbs if one bulb is added to the previous circuit as illustraded in the nearby pictures (2 bulbs in series). Check if you agree

- [ ] There is no change in the brightness of the bulbs
- [ ] The bulbs become brighter
- [ ] The bulbs become dimmer
- [ ] The upper bulb is brighter than the lower bulb

b) WITH COMPUTER Test your prediction by constructing the circuit with the computer. Remember to push she switch down when you are ready. What do you notice (check if you agree)?

- [ ] There is no change in the brightness of the bulbs
- [ ] The bulbs become brighter
- [ ] The bulbs become dimmer
- [ ] The upper bulb is brighter than the lower bulb

c) WITH COMPUTER Measure the voltage of the upper bulb of the circuit with the voltage meter as instructed in the nearby picture

The voltage of the upper bulb is __________ volts.

d) WITH COMPUTER Now, measure the voltage of the lower bulb. The voltage of the lower bulb is ___ volts.

e) What can you say about the voltages of the two bulbs?

- [ ] The voltages are the same
- [ ] The voltages are different

What can be said about the voltages of the lamps in comparison to the voltage of the battery in a two-bulb series circuit (check if you agree)?

- [ ] The voltage of a single bulb and the voltage of the battery are the same
- [ ] The voltage of a single bulb is half of the voltage of the battery
- [ ] The voltage of the battery is divided equally between both bulbs
- [ ] The total voltage of two bulbs is equal to the voltage of the battery
- [ ] The total voltage of two bulbs is half of the voltage of the battery
- [ ] The total voltage of two bulbs is two times the voltage of the battery

Figure 4. The same worksheet example, but now annotated in order to see how the Conceptualization, Investigation and Conclusion phases are incorporated in the worksheets.

Even though the activity has not been designed according to the Ark of Inquiry learning model, it has been designed from the inquiry learning perspective and according to the description does cover some of the phases in the Ark of Inquiry learning model: Conceptualization, Investigation, and Conclusion. This tells that according to the description two of the phases (Orientation and Discussion) are missing, but for those phases that are covered it might be of value to see how they are incorporated in the activity.

The Conceptualization phase: Like already mentioned, the organization of the activity is not around the Ark of Inquiry learning model; rather, it is around worksheets and in a way one could say that most of the worksheets address conceptualization by providing a prediction question to the learners that they are asked to answer without using the computer simulation (see, e.g., Figure 4). The advantage of the organization around worksheets is that it illustrates the cyclic nature of inquiry and that problems can be decomposed into smaller units.

The Investigation phase: Like with Conceptualization, each of the worksheets addresses Investigation. However, from the three sub phases Exploration, Experimentation and Data Interpretation, only the last two are covered in the worksheets. This is in line with the general idea of classifying the proficiency level of the activity on the A level, as typically in A level activities learners are not given much freedom to explore because as a result of their lower proficiency, learners might easily lose track of their investigation processes. It also means that providing more room for exploration could be something to consider if it seems feasible from the perspective of the learners in a particular classroom.

Conclusion – drawing conclusions based on the data: Like with Conceptualization and Investigation, conclusions are dealt with on a worksheet level. This means that although conclusions are part of the inquiry activity, their scope is rather local and paying attention to drawing conclusions also on a more general level might be a consideration in this respect.

Orientation and Discussion: According to the description of the activity, the Orientation and Discussion phases are missing entirely from the activity. As views on science education have changed, its function is no longer viewed as primarily learning science content but also learning to do science including learning to communicate about and reflect on science in relation to society. It is for this reason that the Ark of Inquiry learning model includes Orientation and Discussion as important additions to the more content learning driven inquiry approaches that focus mainly on conceptualize-investigate-conclude cycles.

Scenario 2: Promoting awareness of Responsible Research and Innovation (RRI)

A review of the activity reveals that RRI is addressed in the activity through the general inquiry approach with its purpose of making learners aware of the process of inquiry that is considered to be an important aspect in becoming scientifically literate citizens. However, it also reveals that no explicit references are made in the activity to RRI in the broader sense. Pupils are not asked to connect the activity to the broader context, there is no idea of stakeholders and consequently no clear target for communication and no context for reflection outside the direct scope of the activity. As a result, expected outcomes in terms of developing own views and values in relation are limited, even though the topic of electricity could lend itself for this purpose as it is closely related to energy consumption (one of the grand challenges for societies in the near future). As such it could be a consideration to incorporate RRI in the activity by connecting the activity to this larger issue of energy consumption.

Scenario 3: Empowering girls in science

At first glance the topic of the activity might seem one that is stereotypically thought to be more attractive to boys than to girls and as such one that should be avoided in order to include girls. However, research evidence from 10–15-year-old pupils actually shows that all pupils reported high levels of interest regardless of their gender. The activity therefore seems to be a good example of the importance of avoiding strong stereotyping when thinking of engaging girls in science activities. It illustrates the strength of inquiry learning as an approach to engage young pupils and trigger their interest in science, independent of gender. The activity does not contain any links to scientists or other potential role models that could be utilized to counter the stereotypical view of science as a male occupation.

Scenario 4: Adjusting the proficiency level

According to the description the activity is targeted towards A level proficiency. Because of the design of the simulation that restricts the range of possibilities for inquiry it cannot likely be transformed into a C level activity, but there might be possibilities to change it into a B level activity. The direct scientific evidence reveals that it has been successfully used with pupils on different age and grade levels. This means that even though the activity is classified as an A level activity it already has features that foster pupils with different inquiry proficiency levels and changing the proficiency level may therefore not be the highest priority.

Scenario 5: Adding or improving inquiry phases

In benchmarking the activity against the Ark of Inquiry learning model it became clear that according to the description of the activity only three of the five phases were covered by the activity. That means that two of the phases are entirely missing and because the missing phases Orientation and Discussion are considered important for learning to communicate about and to reflect on science in relation to society, the most obvious consideration would be to look for possibilities to add those to the activity.

Scenario 6: Overcoming language and sociocultural barriers

The description states that the language dependency of the activity is high, but it is clear that this rating is based on using the entire set of worksheets in English. A closer look at the simulation itself reveals that there is actually fairly little language dependency there. Separating simulation from worksheets in the classroom situation might therefore be a consideration addressing the language barrier. The activity does not have much that could be identified as sociocultural (but that could actually be a reason to try to add something in that direction).

Scenario conclusion

The conclusion based on this assessment of the activity along the lines of the six scenarios is that there are a number of changes that likely can and/or should be made to the activity in order to make it fit better in the classroom practices in different classrooms across EU countries. The next section will go through the scenarios once more to address some of these potential changes.

Using the scenario assessment to change the activity

Scenario 1: Introduction to the concept of inquiry learning and the Ark of Inquiry learning model

With regards to the first scenario the main consideration to be made is whether the Ark of Inquiry learning model in itself will be a learning goal for the pupils working with an activity. If learning about the model is not among the goals, using the model to support decisions with regard to the other scenarios will be the main purpose and no action or changes derive directly from the assessment of the activity against the model. If, however, learning about the Ark of Inquiry learning model is among the learning goals for the pupils working with the activity, it is important to realize that organizing an activity according to the Ark of Inquiry learning model will not make pupils learn about that model without making the model explicit. This means that the Ark of Inquiry learning model needs to become visible throughout the activity (and may need to be introduced to the pupils). For the electricity example, one way of doing that is by providing pupils with worksheets that indicate the phases in a way similar to the way it was done in Figure 4 when assessing the activity. Presenting the activity this way could be a good example to illustrate the cyclic nature of inquiry models with the recurring phases on each of the worksheets. At the same time they also illustrate the general idea of breaking up bigger questions into smaller ones first.

Scenario 2: Promoting awareness of Responsible Research and Innovation (RRI)

Assessment of the activity revealed that there was no connection to the broader context, no idea of stakeholders and consequently no clear target for communication and no context for reflection outside the direct scope of the activity. As such the activity provides little opportunity for reflection (individually thinking through), communication (presentation and explanation to an audience), and discussions (questioning with an audience) that will make pupils establish their own views and values. It was also mentioned that in principle the topic of electricity could lend itself well for this purpose as it is closely related to energy consumption, which would provide a wider context for the activity. Obvious choices for adding emphasis on RRI to the activity would be in the Orientation phase (connect to wider context) Conclusion phase (reflection) and Discussion phase (communicating to others), especially since two of these phases are missing from the activity, which would mean including RRI could be combined with adding phases .

Scenario 3: Empowering girls in science

Based on the assessment of the gender dimension there is neither much reason for, nor any obvious way of changing the activity. Research evidence suggests that the activity has been well received by both girls and boys over a considerable age range. Phrased differently, it seems that the activity might be an appreciated addition to the curriculum for the whole classroom.

Scenario 4: Adjusting the proficiency level

In its original form the activity is classified as an A level activity, both because the design of the simulation restricts the range of possibilities for inquiry and because learners' inquiry process is guided carefully by a structured series of nine instructional worksheets that provide a high level of support. As a result of the first, the design of the simulation, the activity probably does not lend itself well for attempting to create a C level proficiency activity (generally A level activities likely do not transform to C level easily). Changing the activity to a B level activity seems, however, feasible, and because the simulation cannot be changed easily, the logical place to look for changes is in the worksheets.

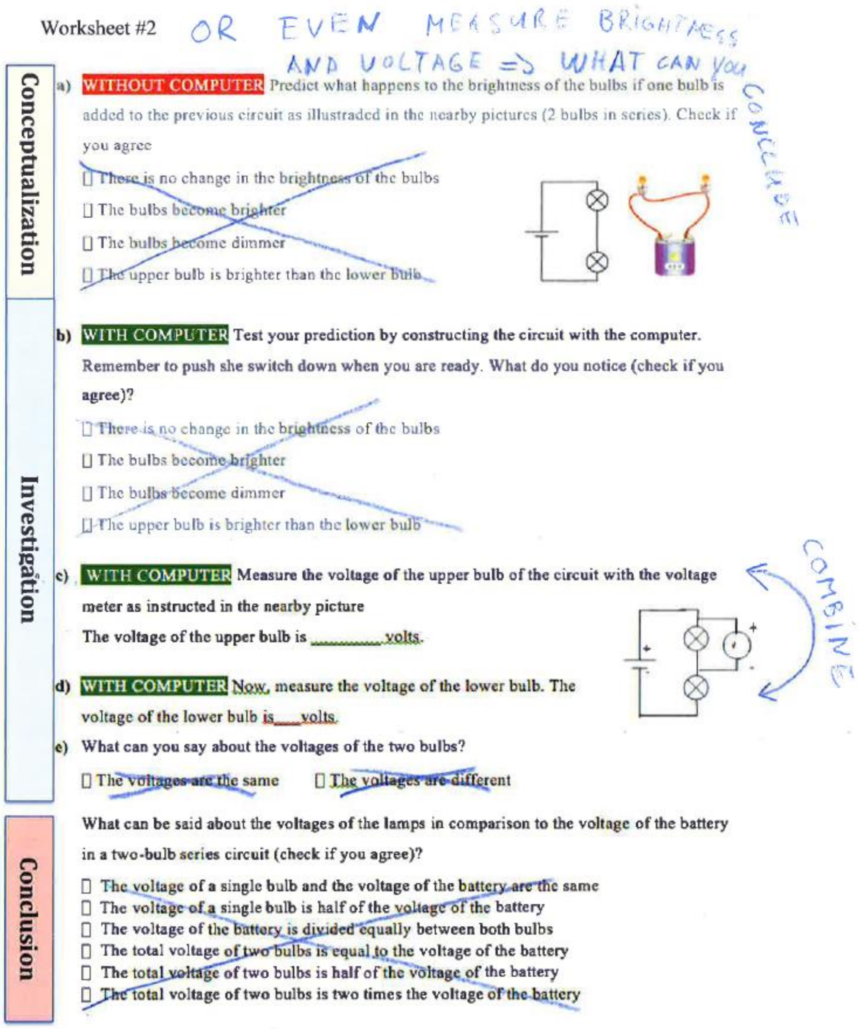


Figure 5. Annotated worksheet for the purpose of changing the proficiency level

Earlier it was already noted that the activity has been successfully used over a rather wide range of ages and grades and that this is an indication that the activity already fosters pupils with different inquiry proficiency levels. A closer inspection of the worksheets shows that this can likely be attributed to the progressive organization of the worksheets that become more open-ended towards the end. In order to make the activity fit B level proficiency, these later worksheets can be taken as an example for restructuring the earlier ones and making these more open-ended as well: for instance, by removing the pre-defined answer alternatives as it is done in Figure 5 and replacing those with open-ended answer slots, even making the whole worksheet structure more open-ended (as will be done in the example below). Doing this has several potentially beneficial side effects in relation to the other scenarios. It can, for instance, be used to introduce exploration in the Investigation phase (which was absent before), create natural opportunities for discussion (also originally absent) based on different solutions created by learners or reduce the language dependency of the activity (see also Scenario 6).

Modified B level activity

Title: Electricity Lab
Domain: Physics
Topic: Electricity, Simple electric circuit
Language: Finnish, English
Language dependency: **Medium**
Typical age range: 11–15
Inquiry proficiency level: **Basic (B)**
Inquiry phases covered: Conceptualization, Investigation, Conclusion

Using the below 4-step example, it is relatively easy to change the proficiency level of the original activity to B level by reducing (or stripping off) the structure and guidance that the worksheets provide.

1. Use one bulb and wire(s) to investigate on which condition the bulb does and does not light. When you succeed to light the bulb, you have successfully created a closed circuit. Always measure the voltage across the bulb after each configuration change and compare the reading to the battery voltage. Also, keep an eye on the bulb brightness after each configuration change. Take notes so that you can reflect on the findings later.
2. Add a second bulb to the circuit and make a configuration where both bulbs will first turn on and both will turn off when a wire is removed. Once you succeed, you have created a two bulb series circuit.
   Based on your experimentation so far, what kind of conclusions (e.g., related to bulb brightness and voltages) can you draw about the underlying circuit laws and principles?
3. Change the previous configuration so that when you again remove one wire, only one of the bulbs will turn off (the other will remain on). Once you succeed, you have created a two bulb parallel circuit.
   Based on your recent experimentation, what kind of conclusions can you draw now about the underlying circuit laws and principles (be open-minded and prepared to change/elaborate on your conception from the earlier phases)?

4. Design a circuit with three bulbs where bulb brightness is the following: A > B = C. Are there different ways you can configure the circuit that confirms the criteria? Draw the circuits.
   Considering all the above experiments that you have conducted, what kind of summary and final conclusions can you draw about the underlying circuit laws and principles?

Apart from leaving more initiative to the learners, these kinds of tasks also bring some advantages for creating discussion opportunities for learners, as the more open-ended nature of the tasks also means that learners can create alternative solutions to the same design problem, which in turn can be the topic for discussion. (e.g., different solutions to a problem, discuss the alternatives, and discuss similarities and differences between the different solutions).

This example showed how an A level activity that was initially very structured and very explicit in its guidance towards the learners can be relatively easily changed into a B level activity by removing explicit guidance and some of the structure. As a side effect it was shown that doing so also creates natural opportunities for discussion, one of the important aspects in the Ark of Inquiry learning model.

Scenario 5: Adding or improving inquiry phases

Although the activity has been found highly effective, the assessment also showed that it can be further improved, because it is incomplete from the point of view of the Ark of Inquiry learning model in the sense that it is missing two of the inquiry phases, namely Orientation and Discussion[2]. These two phases have particularly important roles in the context of the Ark of Inquiry as they provide the connection between activities and the broader societal contexts for which we aim to educate our learners. A meaningful Orientation phase can provide learners with a context that gives relevance to the activity while activating their prior knowledge on the topic. The importance of the Discussion phase is that it can make learners understand that what they have done, how they have done it and how they interpret its meaning is not a final product but an object for discourse and argumentation that initiates reflection and meaning making. This helps to convey the message that nowadays science is inherently a social act that is about collaboration and discourse.

[2]The original activity included even the orientation and discussion phases, but in the context of Ark of Inquiry these phases can be considered weak and/or incomplete. In the original context the orientation phase (that included a general introduction to the topic, worksheets, and the simulation) was given in an oral format (and there is no reason why this could not be provided by a teacher). What should be noted, however, is that even though it could qualify as orientation, it would not qualify as orientation that provided a meaningful context to the pupils in a way that it could be expected to raise pupils' awareness of RRI. The discussion phase was not entirely absent in the reference activity either, because the pupils were working in pairs. However, the discussion in a pair was rather implicit and by no means guaranteed to be fruitful (some of the pairs actually showed very little sign of discussion or even collaboration). It would therefore be advisable to strengthen the discussion by building in something in the activity that makes discussion and the role of discussion in science studies more explicit to the learners.

The following example will highlight how these phases could be added to this inquiry activity in a way that addresses RRI more explicitly in the activity at the same time.

Amended five phase activity

Title: Electricity Lab
Domain: Physics
Topic: Electricity, Simple electric circuit, **Energy consumption**
Language: Finnish, English
Language dependency: High or **Medium**
Typical age range: 11–15
Inquiry proficiency level: Novice (A) or **Basic (**B**)**
Inquiry phases covered: **Orientation**, Conceptualization, Investigation, Conclusion, **Discussion**

In the case of the Electricity Lab activity, depending on the age of learners and their experience with electric circuits, it might be a good idea to build in an Orientation phase that provides a general introduction (the Orientation phase) to the topic of electricity and electric circuits. This can be accomplished, for instance, by asking learners to watch a short introductory video (e.g., https://www.youtube.com/watch?v=EJeAuQ7pkpc) or tutorial (http://scienceofeverydaylife.discoveryeducation.com/views/other.cfm?guidAssetId=D1507F6E-09C3-4E7B-B1E9-16708E402009) on the topic and/or read a more detailed description (http://www.explainthatstuff.com/electricity.html). At the same time, as discussed above in the section on RRI, it is important to connect the activity to a wider societal context and the Orientation phase is also a good place to make that kind of connection. The Compass project, for instance, provides several (extensive) assignments where pupils can learn about the differences between traditional and energy-saving light bulbs (as well as the pros and cons of each) and investigate whether and how much energy can be saved by using energy-saving lamps (http://www.compass-project.eu/resources_detail.php?UG_hodnota_id=4; Figure 6). Combining two activities, where one (from Compass) serves as an Orientation for the other (Electricity) can make activities more meaningful for learners.

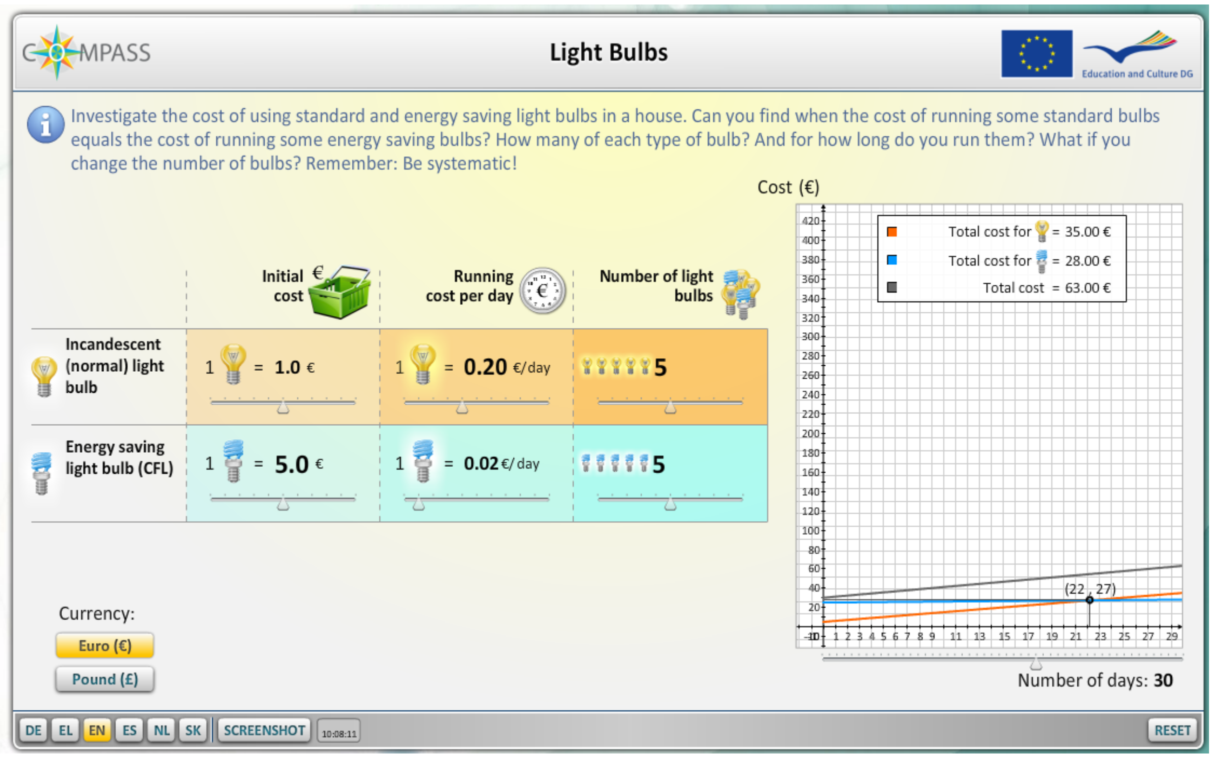


Figure 6. A tool for calculating the costs of traditional vs. energy-saving light bulbs

As mentioned before, the conclusions remain on the worksheet level in this activity and especially in the B level activity, different solutions and conclusions on this level could be used for discussions among pupils. On the more general level one thing that could be done is to include a general conclusion part as well, and this general conclusion part could in turn be connected to Discussion, the other phase that is missing in the activity.

This more general discussion related to the activity could also be expanded to real-life situations and re-linked to the Orientation phase. Learners could, for instance, be asked to reflect on and discuss the differences of series and parallel circuits for energy use, susceptibility to malfunctions in a system (e.g., too many appliances on one power supply) and/or identify examples of such systems in and around their school and home environments, and discuss and examine why they are examples of one or the other (e.g., why the heating element of a hairdryer should not remain working if the blower function breaks down).

Scenario 6: Overcoming language and sociocultural barriers

Having a strict attitude towards language combined with a language that has only a limited amount of users restricts the amount of activities that can be considered, as many activities are developed and published in English and are most often not translated into all languages of the Ark of Inquiry project. Adopting a more flexible approach to language may change that because the question is no longer if activities are available in the target language, but to which extent activities depend on language and on the approach to language of teachers and schools. Formulated more practically, though activities might be in a different language, using them actually might require only fairly little real foreign language understanding and even if they require more, it may still be possible to work around the language dependency or even seize different language activities as an opportunity to integrate content and second language learning.

In the assessment of potential language barriers it was noted that a distinction could be made between language dependency of the simulation and the worksheets for the activity.

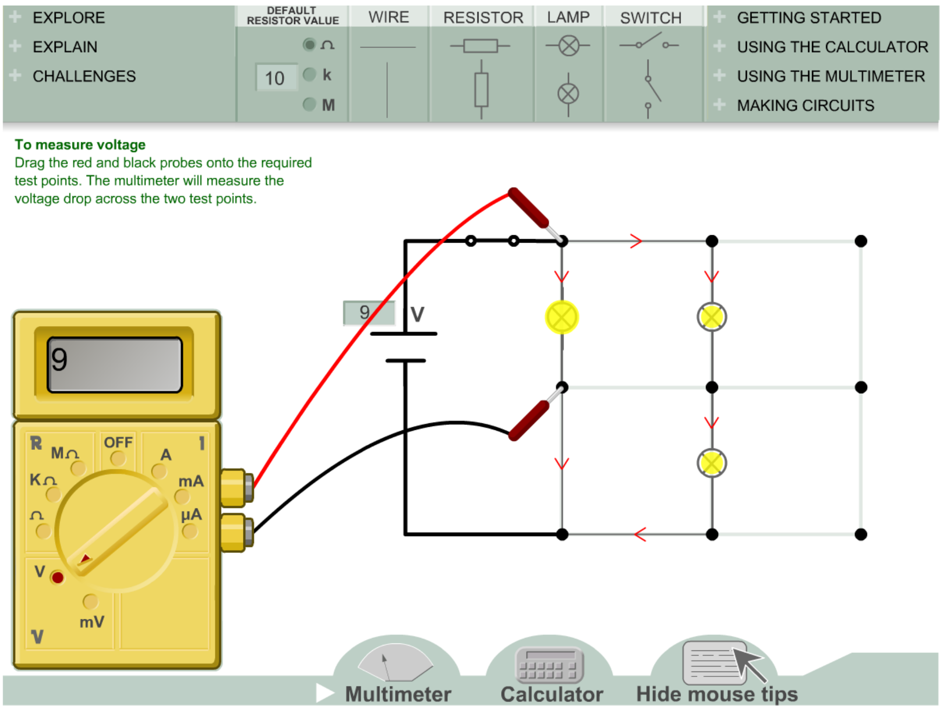
The language dependency of the simulation cannot be altered, but the dependency in itself is low and can be addressed.

Language dependency of the worksheets is high, but it can be altered and addressed in a number of ways.

Simulation

The simulation that is presented in Figure 2 is in principle having a rather low language dependency. Though the simulation is not available in other languages than English and the language cannot be altered, there is a limited number of main concepts of importance, which means that it does not need to be too big of a hurdle for using the resource.

All necessary information could easily be provided on a sheet of paper that pupils can keep next to the computer when they use the resource. The basis for this translation could even be provided by an automatic translation with one of the available translators on the Web and improved where needed (the extent of the second step depends on both the quality of the initial translation and the language level of the pupils). Figure 7 shows an example of this approach for the electricity simulation for use in a Dutch classroom.



wire=draad

resistor = weerstand

lamp = lamp

switch = schakelaar

default resistor value = beginwaarde weerstand

To measure voltage... = Om de spanning te meten: sleep de rode en zwarte meetpennen naar de meetpunten. De multimeter geeft het spanningsverschil tussen de twee meetpunten weer

Figure 7. A glossary with the bare minimum of terms that are used in the activity

Worksheets

With regard to dealing with the language dependency of the worksheets there are two main approaches that can be taken. The first is to lower the language dependency of the worksheets themselves and the second is to treat language as an opportunity to integrate language learning with science learning (the CLIL approach).

Figure 5 in the *Adjusting the proficiency level* scenario can be seen as an illustration of the first approach. Replacing the pre-defined answer alternatives with open answers dramatically reduces the language dependency of the worksheet example. The reformulated worksheets in the example of the *Adjusting the proficiency level* scenario even further reduces the language dependency.

In the context of CLIL again two main approaches could be distinguished. One is addressing the language dependency directly through CLIL; the other is addressing the language dependency through integration of translation of the activities in the language curriculum. The first would mean using the materials as is and integrate teaching science and teaching foreign language (e.g., teaching science is done in English). The second would create a different connection between language teaching and science teaching so that part of the language lesson content is provided through translating science content.

The important message with regard to either approach is that from this perspective, activities in a second language are transformed from a problem to an opportunity for fostering a flexible attitude towards foreign languages.

As said, there are not many pointers to sociocultural aspects in the original activity, but that could actually be a reason for considering adding this aspect. The obvious places to do so would be the Orientation and Discussion phases (the phases missing) as their function could be viewed as providing context, and it would be natural to provide a local context for this purpose.

Example 2: Water quality

The second example will illustrate an inquiry activity on water quality. Similarly to the previous example, first the activity will be described, after that it will be examined from the perspective of the six scenarios, and then based on this assessment some options and ideas for adjusting and improving the activity will be presented based on the same scenarios with the underlying idea of improving the overall fit of the activity in a certain classroom situation.

Description of the activity

Title: Water Quality
Domains: Maths, Chemistry, Biology, Environmental Education
Topic: Quality of potable and swimming water, measurement procedures and EU criteria
Language: English, German, Dutch, Greek, Spanish, Slovak
Language dependency: High
Typical age range: 14–16
Inquiry proficiency level: Novice (A)
Inquiry phases covered: Orientation, Conceptualization, Investigation, Conclusion, and Discussion


COMPASS

Water quality – Worksheet| 1

Worksheets for task 1

Brussels, 11 June 2009

Bathing water quality improving in the EU

The annual bathing water report presented today by the European Commission and the European Environment Agency reveals that the large majority of bathing sites across the European Union met EU hygiene standards in 2008. During that bathing season some 96% of coastal bathing areas and 92% of bathing sites in rivers and lakes complied with minimum standards. The report provides useful water quality information for the millions of people who visit Europe's beaches every summer.

Commissioner for the Environment Stavros Dimas said: "High quality bathing water is essential for the well-being of European citizens and the environment – and this goes for all other bodies of water too. I am pleased to see that the overall quality of water in bathing areas is improving throughout the Union."

Professor Jacqueline McGlade, Executive Director of the European Environment Agency, added, "Information sources like this report and our web-based viewing tools enable citizens not only to check the quality of the bathing water in their local community or holiday destination, but also to allow them to get more actively involved in the protection of their environment."

Of the 21,400 bathing areas monitored throughout the European Union in 2008 two thirds were on the coast and the rest were along rivers and lakes. The largest number of coastal bathing waters can be found in Italy, Greece, France, Spain and Denmark while Germany and France have the highest number of inland bathing waters.

The overall quality of bathing waters in the EU has markedly improved since 1990. Compliance with mandatory values (minimum quality requirements) increased over the 1990 to 2008 period from 80% to 96% and from 52% to 92% in coastal and inland waters respectively. From 2007 to 2008 compliance increased both for inland and coastal waters (1.1 and 3.3 percentage points respectively).

[http://europa.eu/rapid/pressReleasesAction.do?reference=IP/09/903]

Figure 8. A worksheet example of the original activity. The article is taken from a newspaper and functions as an introduction to the pollution of swimming water.

This inquiry activity consists of separate tasks through which pupils explore the topic of water quality, the procedures determined and applied for the examination of swimming water, the criteria of the Blue Flag and the guidelines of water quality assessment for EU countries. The final product of the activity is to write a report to be sent to the local tourist office and provide a summary of the research undertaken as well as advice regarding the quality of the swimming water of the nearby area.

In the example demonstrated in Figure 8, learners are asked to read an article from a newspaper on the pollution and quality of swimming water (Summer 2010). The worksheet serves as Orientation phase where learners can get a brief idea about the issue they will deal with. At this point it is suggested that a person who is involved in water treatment or testing is invited to introduce the subject, elaborate on different areas and answer pupils' questions. After reading the article a group discussion should be held. In the next step, the Conceptualization phase, pupils will learn about the guidelines for assessing water quality as those are stated in the context of the Blue Flag programme. They will also recognize the benefits of those generally accepted criteria when checking the quality of swimming water and will also understand the reasons behind their selection. To achieve this, they test their own water samples determining their own criteria. These can be presented on posters or as PowerPoint presentations in the classroom. Pupils learn to collect and handle data and create measures to maintain water quality. In order to agree on what the criteria of water quality assessment should be, they will first discuss the criteria that have been used and then compare them to the legal requirements that apply within the EU.

In the actual Investigation phase, pupils will test their own water samples to see if they meet the Blue Flag criteria and share their findings with others. To investigate this, they will make use of the test kit to check water quality for pH-value, nitrite and cyanobacteria as well as to test for E-coli bacteria and transparency (turbidity). Once they have the results they can check whether they meet the Blue Flag requirements and also compare them with their fellow pupils' findings. Explanations about differences related to the location of sampling collection will also be discussed.

The Conclusion phase involves reflection on the procedure followed during the testing process and to what extent it influences accuracy. The aim is that the learners become aware of the fact that results may not be considered accurate and that this uncertainty should be mentioned in any advice issued. The comparison and interpretation of other countries' diagrams and the differences between the numbers, types and spread of swimming areas is a task included at this phase as well so that learners can draw conclusions in a broader (inter)national context.

Although each of the inquiry phases here includes discussions, the final product of this learning activity is that pupils summarize the research they carried out in a report to be sent to the local tourist office and provide advice regarding the quality of the local water in regard to whether it is suitable to swim in it.

The learning activity aims at enhancing problem solving and inquiry learning through engaging tasks that familiarize learners with important concepts bridging mathematics with doing science in a framework of real-world issues. The combination of STEM with real-world issues is more likely to promote the transfer of knowledge (both content and procedural) to other contexts also.

Water quality – Worksheet| 12

Worksheets for task 6

Task 6.1: Interpret and compare graphs

The four figures below show compliance with the set norms in the Netherlands and Spain of inland swimming water and of seaside bathing zones.

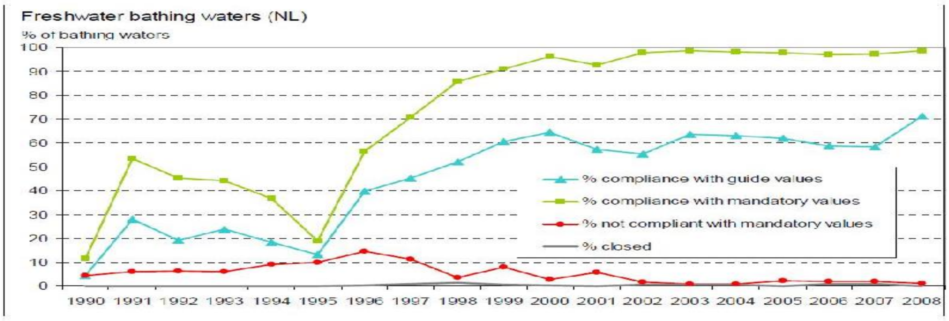


Figure 1

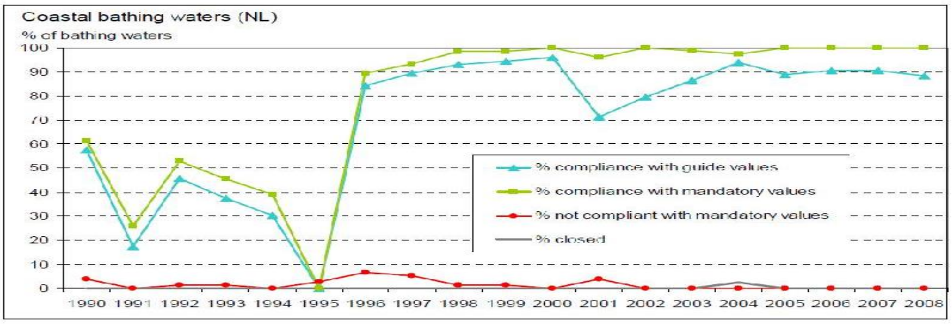


Figure 2

A. Comparing figures 1 and 2; what can you conclude?

B. According to the graphs, were there any notable years? What is special about these years?

Figure 9. A worksheet example from the original activity. The pupils are given graphs of swimming water and bathing zones in the Netherlands.

Water quality – Worksheet| 13

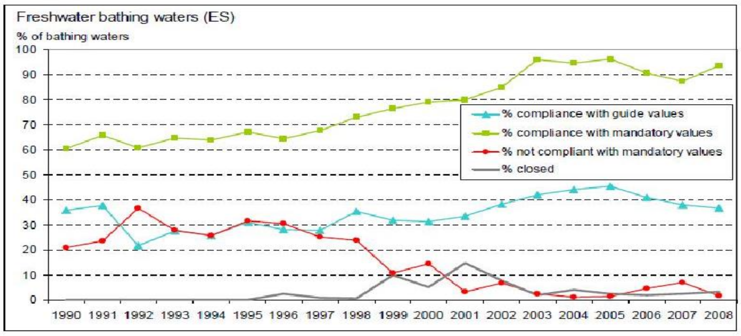


Figure 3

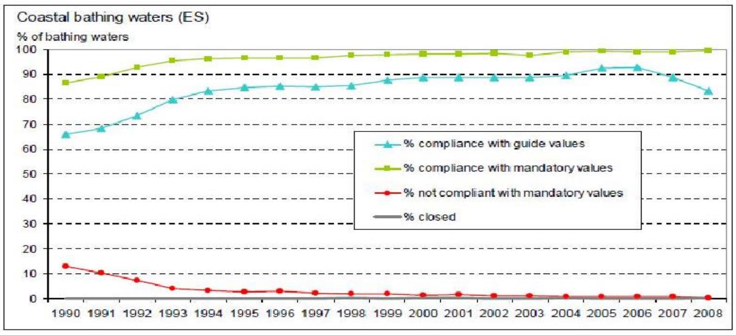


Figure 4

C. Comparing figures 3 and 4; what can you conclude?

D. What can you say about the difference in quality between the two countries? Which country has a better water quality?

Figure 10. A worksheet example from the original activity. The pupils are given graphs of swimming water and bathing zones in Spain.

Assessing the activity from the perspective of the six scenarios

In this part of the document the activity will be assessed from the perspective of each of the six scenarios. Based on this review a few suggestions are made regarding adaptations and amendments in order to improve its overall fit in a certain classroom situation.

Scenario 1: Introduction to the concept of inquiry learning and the Ark of Inquiry learning model

The water quality activity has not been designed and developed according to the Ark of Inquiry learning model. This is why its numerous tasks are not indicating the phases as they are presented in the Ark of Inquiry learning model. However, if among the goals is familiarizing the pupils with this model, then the phases should be identified in the inquiry activity and presented to the learners during the learning process.

Table 2: Mapping of the tasks on the inquiry learning phase to which they belong in order to see how the five inquiry phases are incorporated in the tasks.

<table>
<tr><th>Inquiry phases</th><th colspan="3">Tasks</th><th rowspan="4">DISCUSSION</th></tr>
<tr><td>ORIENTATION</td><td colspan="3">Task 1: Introduction to the topic
The pupils are given an article to read; discussion either with a specialist on the topic or with fellow pupils can focus on the following questions:
- Is our swimming water clean enough?
- Why is purity an important consideration?
- How is this purity checked?
- How can the quality be maintained?
- Who checks this?
- Is approved swimming water potable (safe for drinking)?</td></tr>
<tr><td>CONCEPTUALIZATION</td><td>Task 2: How can water be tested for quality?
Working in groups of 3 or 4, learners should determine their criteria for water quality. The results and opinions can be presented on posters, transparencies or in a PowerPoint presentation. These can then be used for a class discussion.</td><td>Task 3: The Blue Flag criteria
Learning about the criteria of the ‘Blue Flag’ as well as how to apply those criteria. Pupils will also set up a plan for the testing procedure. Optionally, a comparison with the directives for drinking water can be explored.</td><td>Task 3: Are the criteria trustworthy?
Norms of chemical and biological parameters: accuracy. Advantages and disadvantages of methods.
Optional: Logarithmic relationship between concentration and pH-value</td></tr>
<tr><td>INVESTIGATION</td><td colspan="3">Task 4: Test the water quality of the samples
The pupils test their own water samples to see if they meet the Blue Flag criteria and share their findings. They will consider reliability with respect to taking and collecting samples. Other criteria selected by individuals or groups may be tested as well. Testing procedures:
• Application of the test kit to check water quality for pH-value, nitrite and (optionally) also for cyanobacteria (nitrate and phosphate).
• Test samples for E-coli (bacteria) and other biological materials.
• Test samples for acid, chloride, and nitrite.</td></tr>
</table>

CONCLUSION	**Task 5: Are the measurement results reliable?** The pupils reflect on the procedure followed during the testing process and to what extent it influences accuracy. Pupils consider the limited accuracy of the (colour) indicator test, using copper sulphate.	**Task 6: Comparison with other countries.** Comparison between the Netherlands and Spain through graphs and maps provided. Interpretation of the figures. Learners should identify differences in numbers, types and spread of swimming areas.	
DISCUSSION	**Task 7: Report to the local tourist office** The pupils summarize all the research they have carried out and provide advice for the local tourist office. They need to give clear advice through their report on whether the water is safe.		

Even though the activity has not been designed according to the Ark of Inquiry learning model, it has been designed from an inquiry learning perspective and according to the description does cover all five phases in the Ark of Inquiry learning model. Below is a description of how these phases are incorporated in the activity.

Orientation: As mentioned earlier, although the activity has not been designed having the Ark of Inquiry learning model as a base, the Orientation phase is addressed at the beginning of the activity – by the article provided to the pupils – in order to introduce them to the topic.

Conceptualization: Similarly to Orientation, Conceptualization is also addressed in the second and third tasks by first asking the pupils to predict the criteria for water quality without yet checking which of those are the Blue Flag criteria. At this phase pupils are also going to create a plan for the testing procedure which will be conducted during the next phase, that of Investigation. This phase could be regarded as deviating from the rest of the activity in respect to the inquiry proficiency level since it provides some space to the learners to explore, share and discuss their ideas about the criteria of water quality before they are presented with the criteria determined by the Blue Flag. Thus, it could be regarded as a B level/basic inquiry phase.

Investigation: Like the previous phases, the fourth task addresses Investigation. At this point learners conduct actual tests and measurements and are fully guided on what they will examine and what checks they will perform. Thus, they are not given much freedom to explore because as described in the previous example as well, their lack of inquiry skills at this stage might pose them obstacles during investigation. However, adjusting the activity to fit the needs and skills of the learners so that it allows for more independent exploration is also feasible and will be described in a later section of this document.

Conclusion: Conclusion as a phase is also covered through the tasks five and six in the activity. The pupils are asked to reflect on a more general level on the procedures they followed. The scope is broader than just focusing on the results of the tests they performed. They are mostly asked to draw conclusions about the accuracy and reliability of those procedures and measurements. Moreover, they are asked to apply the knowledge and ideas they acquired so far in order to compare the information about different countries and draw conclusions on a more general (inter)national context. This phase could also be regarded as a B level activity in respect to the inquiry proficiency level since it encourages the learners to develop their own views on the procedures followed and their accuracy.

Discussion: Unlike many other activities, this activity has another element that could be considered a strength. Apart from addressing discussion in a separate task, it also encourages discussions and moments of reflection throughout the whole activity in each phase. For example, in the Orientation phase reading the article is followed by a discussion on the topic with fellow pupils. It is also suggested that an expert on the topic is invited for discussion with the pupils. Also, in the Conceptualization phase the learners are asked to think critically and discuss whether the criteria determined are trustworthy as well as the advantages and disadvantages of various methods. In the Investigation phase, after the pupils test their own water samples to see if they meet the Blue Flag criteria, they share their findings with their classmates. They are also asked to consider reliability with respect to taking and collecting samples. Finally, in the Conclusion phase the pupils are asked to think and discuss about the accuracy and reliability of the procedures and measurements conducted so far.

This is an important feature because it illustrates the cyclic nature that inquiry should follow. In other words, it is of considerable value that activities do not focus merely on science learning content, but also promote that learners critically consider the impact of various everyday practices as well as the applications of science and its procedures. Moreover, the discussion of ideas and opinions as well as the presentation of findings in many stages of the inquiry process contributes to the development of critical thinking skills as well as to the acquisition of communication skills, which are very important both for achieving transparency during the inquiry process and for sharing scientific findings with a wider societal audience (stakeholders, other scientists, policy makers, etc.).

Discussion as a phase is addressed in the activity in the last task. Pupils are asked to summarize their results in a report for the local tourist office where they will also include concrete advice about the purity of the swimming water and whether it is appropriate and safe for swimming. This is a good example of a Discussion phase that might enhance the sense of responsibility of the pupils in regard to society. First because they need to exhibit accurate results and follow reliable procedures and second because the outcome of their inquiry can benefit others outside their classroom borders.

Scenario 2: Promoting awareness of Responsible Research and Innovation (RRI)

A review of the activity reveals that RRI is addressed in the activity in many ways. First of all the activity is designed in order to provide inquiry learning tasks. Adopting the general inquiry approach is considered to be an important aspect of an activity in creating scientifically literate citizens, thus a way that RRI is incorporated in an activity. Moreover, the activity deals with a real life problem, which is the pollution of water and the water quality. In fact, the activity's main focus is not just the acquisition of mathematic skills and knowledge on how to conduct the testing procedures but also the importance of water purity.

Moreover, among the issues that the pupils are dealing with in this activity are the criteria and measures to ensure reliable results as well as how the quality of water can be maintained (these points are already addressed during the Orientation phase). That way they are developing the idea of research responsibility in producing reliable results, which is a strong RRI feature. Additionally, during the Conceptualization phase the learners are asked to think and discuss the advantages and disadvantages of the various methods for testing water quality. Identifying the impact of the various scientific practices on the environmental, societal or scientific level is also considered as a way to incorporate RRI in an activity.

The same holds for the Conclusion phase, where they are asked to reflect upon the procedures followed in regard to accuracy and what influences that. This feature of the activity allows learners to shift to a more holistic way of thinking able to deal with the complex web of relationships and interdependencies as well as unpredictability. In the same phase pupils are given real data from two countries – the Netherlands and Spain – which they have to compare and draw conclusions. This is also an important RRI feature since it provides them a context for reflection outside the direct scope of testing water quality.

Furthermore, presentations of findings, discussions and communication of the results with the pupils and the teacher as an audience are encouraged in each inquiry phase of the learning activity. Last but not least, the final product of the activity, the report for the local tourist office targets the communication with the stakeholders and can also be viewed as a step towards preparing for and taking action. Preparing for and experiencing participation requires knowledge of all the previous levels and is the most demanding of all the four levels. Thus, including a task which fosters pupils' involvement in RRI and their ability to use science in everyday problem solving adds to the educational value of the activity.

Scenario 3: Empowering girls in science

Inquiry learning and doing science is in itself a way to attract girls' interest and empower them in the field of science. Moreover, the activity contains the suggestion to invite a scientist who is a specialist on water treatment. A female professional on the topic could function as a potential role model and could be utilized to counter the stereotypical view of science as a male occupation.

Scenario 4: Adjusting the proficiency level

According to the description, the inquiry proficiency level of the activity can be considered as A level with the exception of the Conceptualization and Conclusion phases, which could be regarded as B level. Overall, the water quality activity is evaluated as A level because the inquiry process is predefined by a set of worksheets that include structured tasks and do not allow for independent exploration and decision making within the inquiry process. The worksheets also provide a high level of support and all the background information needed in most of the phases. However, there might be possibilities to change the A level phases into a B level if needed.

Scenario 5: Adding or improving inquiry phases

In mapping the activity onto the phases of the Ark of Inquiry learning model it was apparent that according to the description of the activity all five phases were covered by the activity. Thus, in this case there would be no need for further change regarding the addition of inquiry phases.

Scenario 6: Overcoming language and sociocultural barriers

The language dependency of the activity is regarded as high according to the description of the activity. However, the activity is available in six languages – English, German, Dutch, Greek, Spanish, Slovak – most of which are spoken in more than one country. This is quite helpful since it covers more language options than other activities usually do.

Moreover, the evaluation of the language dependency is made with the premise of using the entire set of worksheets and materials in those six languages provided. However, if one likes the activity overall, but pupils are not native speakers of any of these languages, they could make changes and adaptations that eliminate the language dependency of the activity.

Regarding the sociocultural barriers, the activity could be considered a good example of taking sociocultural dimensions into account. The task of collecting water samples in the activity does not pose restrictions on where these samples should be taken. This leaves the choice of localization up to the teacher, who can decide depending on the school's surroundings whether the (swimming) water source should be the nearest river, lake, sea etc. In addition, the task of comparing the graphs of Spain's and the Netherlands' swimming water (though it may originally be meant to illustrate the differences between different geographical regions) is an element that can actually be used to raise awareness of sociocultural aspects. Making this feature of the activity explicit also to the pupils can raise their awareness on the sociocultural aspects and make them recognize these in the future as well.

Scenario conclusion

After assessing the activity with the six scenarios as a reference point we can conclude that there are only a few changes/additions that should be made to the activity in order to adjust it to different classroom situations across the EU countries. The next section presents potential changes to be made in the activity from the perspective of the six scenarios.

Using scenario assessment to change the activity

Scenario 1: Introduction to the concept of inquiry learning and the Ark of Inquiry learning model

Considering the first scenario, in the case of this specific activity the situation is helpful towards teaching about the Ark of Inquiry learning model, as long as learning about the Ark of Inquiry learning model is among the learning goals for the pupils working with the activity. Because the activity is organized according to the Ark of Inquiry learning model (although it was not primarily designed according to it), it can be easily mapped on the Ark of Inquiry learning model. If learning about the Ark of Inquiry learning model is important it should be shown to the pupils to familiarize them with the model. For the Ark of Inquiry learning model to become explicit throughout the activity one could, for example, either provide them with an outline of the tasks that indicates the phases in a way similar to the way it was done in Table 2 or demonstrate the phase under process in each worksheet separately. This way the pupils will become more familiar with the model itself, how the activity is organized and what aims and procedures are involved in each phase.

Scenario 2: Promoting awareness of Responsible Research and Innovation (RRI)

The assessment of RRI in relation to the activity shows a strong connection of the learning content to the broader context. The activity promotes reflection outside the direct scope of the activity (individually thinking through), several moments of discussion (questioning with an audience) that allows learners to create and establish their own views and values as well as the idea of a clear target for communication (presentation and explanation to a tourist office). Thus, this activity could function as a good reference point/example when assessing other activities in order to detect whether the RRI element is present or needs to be added/strengthened.

Scenario 3: Empowering girls in science

The assessment of the gender dimension of the activity showed that inquiry learning was already a helpful tool for girls' empowerment in science. Apart from that there is also a suggestion to invite a scientist who is a specialist on water treatment. A female professional on the topic could be viewed as a potential role model and could be utilized to counter the stereotypical view of science as a male occupation. Thus, this could be a good way to enhance girls' empowerment in science during this activity.

Scenario 4: Adjusting the proficiency level

Regarding the proficiency level of the activity, in its original form it is categorized as an A level activity with the exception of the Conceptualization and Conclusion phases, which are B level. Since there is a given range of tasks in the worksheets provided for the activity it might not be feasible to turn it to a C level activity because using the worksheets already involves an amount of structure. However, changing the inquiry level of the activity to B level seems feasible.

Taking a look at the tasks which belong to the Conceptualization phase, which is B level, we can spot that the questions are more open-ended and the learners have to also use their critical thinking in order to judge between what they have learned so far and provide sound explanations to the questions. Thus, we could follow a similar path for raising the inquiry proficiency level where needed.

Regarding the Orientation phase, to raise the inquiry proficiency level, less structure or support should be provided to the learners during that phase. In the given worksheets the learners are provided with an article on water pollution and quality and the teacher is supposed to provide them with more information during the lesson (this extra information is included in the teacher worksheets). An alternative would be to provide less background and have the learners search for the Blue Flag water quality criteria themselves. Moreover, since at this stage it is recommended to invite a specialist on the topic of water treatment to introduce the learners to the topic, there could be the alternative that the introduction from the specialist's side is shorter and that the learners are asked beforehand to prepare the questions that they would like to discuss during that session.

As for the Investigation phase, the worksheets include guidelines regarding the tests that the learners should perform. That could be changed to asking the learners to decide, based on what they have learned so far, on what they should test the water for and write down their results.

Considering the Discussion phase, we could change its level by asking the pupils to look for and choose the stakeholders to which they will send the report and they could also be given the freedom to decide on what their report could include based on the inquiry they have gone through.

Doing all the above might also have potential side effects that would benefit other scenarios at the same time. For example, it could reduce the language dependency of the activity (see also Scenario 6).

Scenario 5: Adding or improving inquiry phases

The activity seems complete from the point of view of the Ark of Inquiry learning model. Thus, we would not recommend any changes in this respect unless changes are required for the activity to fit the local needs (see also next scenario).

Scenario 6: Overcoming language and sociocultural barriers

As described already, adopting a narrow approach in considering activities judging only by the language availability can limit significantly the amount of activities to be used since there are many that are only available in English. Thus, being more flexible towards the selection of the activities and focusing more on whether the activity depends much or less on the language would increase the range of available choices.

In the specific case of the water quality activity the language dependency of the worksheets is high, but the activity is available in six languages, which increases the chances that it is available in the language you are looking for. If this is not the case, then there is still space for the situation to be altered. In order to address the language barrier to also use the activity in contexts where none of the six languages available is used, a first consideration is to lower the language dependency of the worksheets by excluding the material that contains background information (information sheets) and ask pupils to search for those on their own (e.g., the criteria of the Blue Flag) using online resources, the school/city library, etc. As it was presented above, this alternative was also helpful in increasing the inquiry proficiency level of the activity, which means that making changes in one scenario can also have side effects for other scenarios.

Moreover, translating and providing to the pupils only the questions of the various tasks could significantly reduce the language dependency and still make it possible to conduct the activity. Furthermore, the introductory information at the beginning of the tasks could also be translated and given to the learners orally in their native language so that they get a minimum amount of text. Online translators could also help in making the translation faster and easier, at least by providing a first basis on which the teacher can work further for optimum language use.

Finally, as it was also mentioned in the previous example, activities in a second language can either be viewed as a problem or as an opportunity for enhancing flexibility towards foreign languages. A suggestion to the language barrier would be to treat language as an opportunity rather than as a barrier in order to integrate language learning with science learning (the CLIL approach). In the case of the water quality activity, a way to realize this alternative would be that the pupils are given the newspaper article (the one available in the Orientation phase) in a second language, in English, for instance (if English is not their native language). This would be a good way for the learners to practise their skills on a second language by having to translate it in order to comprehend it.

3. Conclusions

This deliverable presented six pedagogical scenarios that are designed to enhance the uptake and use of inquiry activities across schools in Europe in the context of the Ark of Inquiry project. These scenarios that build on the existing work in the project are generic in nature, meaning that each scenario can be implemented in relation to any inquiry activity inside and outside of the project where the scenario applies to. The scenarios are targeted at teachers with the idea that the scenarios will help them to evaluate, author, amend and adapt existing inquiry activities to fit these better to their specific needs and goals in the school environment. Even though the scenarios are targeted at teachers, they can also be used by other stakeholders to help them design and structure inquiry activities in such manner that the activities meet the general requirements of the Ark of Inquiry project.

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Appendix

Inquiry proficiency levels

Within the Inquiry Proficiency Framework, the degree of challenge presented by an inquiry activity is determined by three dimensions: problem-solving type (from well-defined to ill-defined), learner autonomy (initiated and led by the teacher and/or by activity materials to learner- initiated and led), and learner awareness of Responsible Research and Innovation (from reporting to teacher and maybe fellow pupils to addressing relevance of research and research findings to people and society). Inquiry activities can be divided into the following three proficiency levels: A-Novice, B-Basic, and C-Advanced.

- At the lowest, Novice level (A) activities aim mainly at engaging learners in and introducing them to structured inquiry activities.
- At the Basic level (B) the inquiry activities become semi-structured and guide learners towards independency related to knowing how to inquire and reflection on and discussion related to the activity.
- At the Advanced level (C) learners can already shape their own inquiry activities and reflect and discuss outcomes in collaboration with diverse stakeholders.

INQUIRY PHASE	INQUIRY PROFICIENCY LEVEL		
	A (basic inquiry)	B (advanced inquiry)	C (expert inquiry)
ORIENTATION	Learners are introduced to a problem within a well-defined problem space	Learners are introduced to a problem in a semi-structured problem space	Learners identify a suitable problem in an open-ended problem space
CONCEPTUALIZATION	Learners are led to common questions and/or hypotheses that will be studied in the investigation	Learners formulate questions and/or hypotheses through guidance	Learners explore and formulate meaningful questions and hypotheses
INVESTIGATION	Learners collect and analyse data according to prescribed procedures and fixed instruments	Learners collect and analyse data in semi-structured steps and formats	Learners operationalize procedures and formats through which they collect and analyse data
CONCLUSION	Learners reach an understanding of fixed conclusions	Learners reach conclusions through (semi-)structured procedures	Learners reach conclusions and explain the process
DISCUSSION	Learners present in fixed formats to teachers and/or peers	Learners present and communicate in semi-structured or self-chosen formats to teachers and/or peers	Learners present and discuss at appropriate times and in applicable formats with diverse stakeholders