Venice Office
Regional Bureau for Science and Culture in Europe

United Nations Educational, Scientific and Cultural Organization

Introduction to Inquiry

An Online Course for Teachers to Learn about the Inquiry Learning Cycle

Link to online course:

http://www.unesco.org/new/en/venice/resources-services/host-facilities/special-events/ark-of-inquiry/

Ark of Inquiry: Inquiry Awards for Youth over Europe" is a project on teacher training, oriented towards raising science awareness, particularly that of youth aged 7 to 18, to Responsible Research and Innovation, (RRI). It is a coordination and support action under FP7-SCIENCE-IN-SOCIETY-2013-1, ACTIVITY 5.2.2 Young people and science: Topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 612252.

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0. To help you get started…

Who is this course for?

This course is mainly designed for science teachers at primary or secondary schools who would like to learn more about inquiry-based learning and how to use it in the classroom.

It has been shown that inquiry-based science education (IBSE) can increase pupils' interest in science and motivate teachers in and out of the classroom. Pupils describe inquiry-based learning as a fun way of learning exciting new things without even noticing. There are numerous useful inquiry-based learning methods available, but these methods are not being widely implemented.

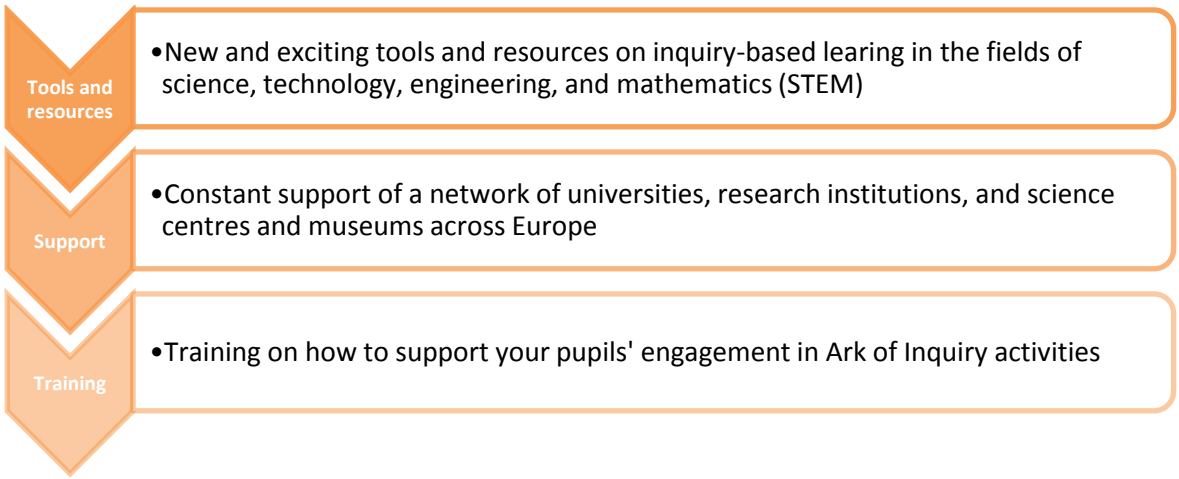
We aim to engage teachers around Europe in educating a new generation of pupils who understand the inquiry process, are familiar with Responsible Research and Innovation (RRI) practices, and thus, who could develop a desire to commit to a career in science in the future, a domain of utmost importance in our society.

What will you get out of it?

The course is designed to provide teachers with an overview to the inquiry process and to introduce them to their specific role in the Ark of Inquiry project; namely, on how teachers can support their pupils in the Ark of Inquiry activities and provide constructive feedback on pupils' completed inquiry activities.

The success and sustainability of the Ark of Inquiry project depends on the community that will support pupils in their inquiry learning. This means that you, teachers, are the key to everyone's success!

After taking this course, if you decide to participate in the Ark of Inquiry project, you will have access to:



How do I access the course?

This course, designed and developed by the UNESCO Regional Bureau for Science and Culture in Europe (Venice, Italy), is based on the web-based training materials provided on the main Ark of Inquiry website (www.arkofinquiry.eu). The course can be accessed in both English and Italian from UNESCO's website **here**.

This course is also available in a **downloadable PDF version** from the UNESCO website.

Instructions for use

The course is broken into four sections:

Each section can be done sequentially, or the user can move around the course to look for specific information as needed.

For information on **how to navigate the course online**, please see the section labelled at the bottom of the pages online.

1. Introduction to the project: Ark of Inquiry: Inquiry Awards for Youth Over Europe

Project Description

Ark of Inquiry: Inquiry Awards for Youth over Europe is a research and development project funded by the European Commission, involving 13 project partners from 12 countries.

In this project, a platform is being developed through which carefully selected inquiry-based activities will be made widely available across Europe. This platform will bring together inquiry-based activities, learners, and supporters (teachers, university students, researchers, staff of the museums, and universities).

To specifically support teachers, the Ark of Inquiry project will provide face-to-face and/or online training for them so that they will be able to support and motivate the pupils in their inquiry-based activities. Furthermore, supportive web-based materials will be developed for all of the supporters working with the Ark of Inquiry project.

The Ark of Inquiry project will also:

- create a pedagogical framework that is challenging to pupils and can be implemented with the support of teachers and other members of the supporting community;
- develop instruments for evaluating learners' inquiry skills and experiences in order to ensure progress and to provide pupils with meaningful feedback on their inquiry progress; and,
- design an awards system for the pupils to motivate them to improve their inquiry skills and to recognize their achievements.

Goals and objectives

Targeting pupils 7 to 18 years of age around Europe, the overall aim of the Ark of Inquiry project is to create a "new science classroom," one which would provide more challenging, authentic, and higher-order learning experiences and more opportunities for pupils to participate in scientific practices and tasks, using the discourse of science and working with scientific representations and tools.

To support learners' inquiry activities and their performance during the four years of the project, it aims to:

- educate 23,000 students;
- train 1,100 teachers;
- engage 100 science and teacher education students; and
- connect 50 researchers from universities and science centres and museums

Policy-makers and parents are also being targeted to support the inclusion of inquiry-based science education in both legislative and in the home decision-making.

The platform will connect formal learning settings and curricula to centres for science and research, so that different generations of scientists can interact with each other and provide mutual support.

2. Responsible Research and Innovation (RRI) and Inquiry

What is Responsible Research and Innovation (RRI)?

Responsible Research and Innovation (RRI) is an inclusive approach that allows citizens to decide on new technologies within their society. This way, citizens are able to evaluate research and develop critical questioning skills regarding new technologies in society and education. The greater the involvement of informed citizens in RRI, the greater the public trust on any technological enterprise and the more ethical and educated the decisions.

The Ark of Inquiry project aims to foster RRI by teaching pupils core inquiry skills needed to evaluate scientific research and by offering opportunities for pupils to engage with different societal actors involved in the research and innovation process. RRI emphasizes the importance of communication and dialogue, and in the Ark of Inquiry project, students have the opportunity to discuss science with multiple stakeholders.

Additionally, as the issue of gender is also a parameter in science education, one of the dimensions of RRI is gender equality which can be achieved in two ways: 1) by providing active learner-centered learning environments that connect activities to environmental, societal, and “everyday-life” contexts; and 2) by providing female role models and mentors in or around the activities.

What is Inquiry?

The meaning of inquiry refers mainly to “asking questions.” However, it can also be defined as an RRI process that aims to obtain scientific knowledge, resolving doubt, or solving a problem. More specifically, inquiry is an approach to learning that involves a process of exploring the natural or material world by asking questions, making discoveries, and testing. Inquiry, in the context of science and education, should mirror as closely as possible the enterprise of doing real science (National Science Foundation, 2000).

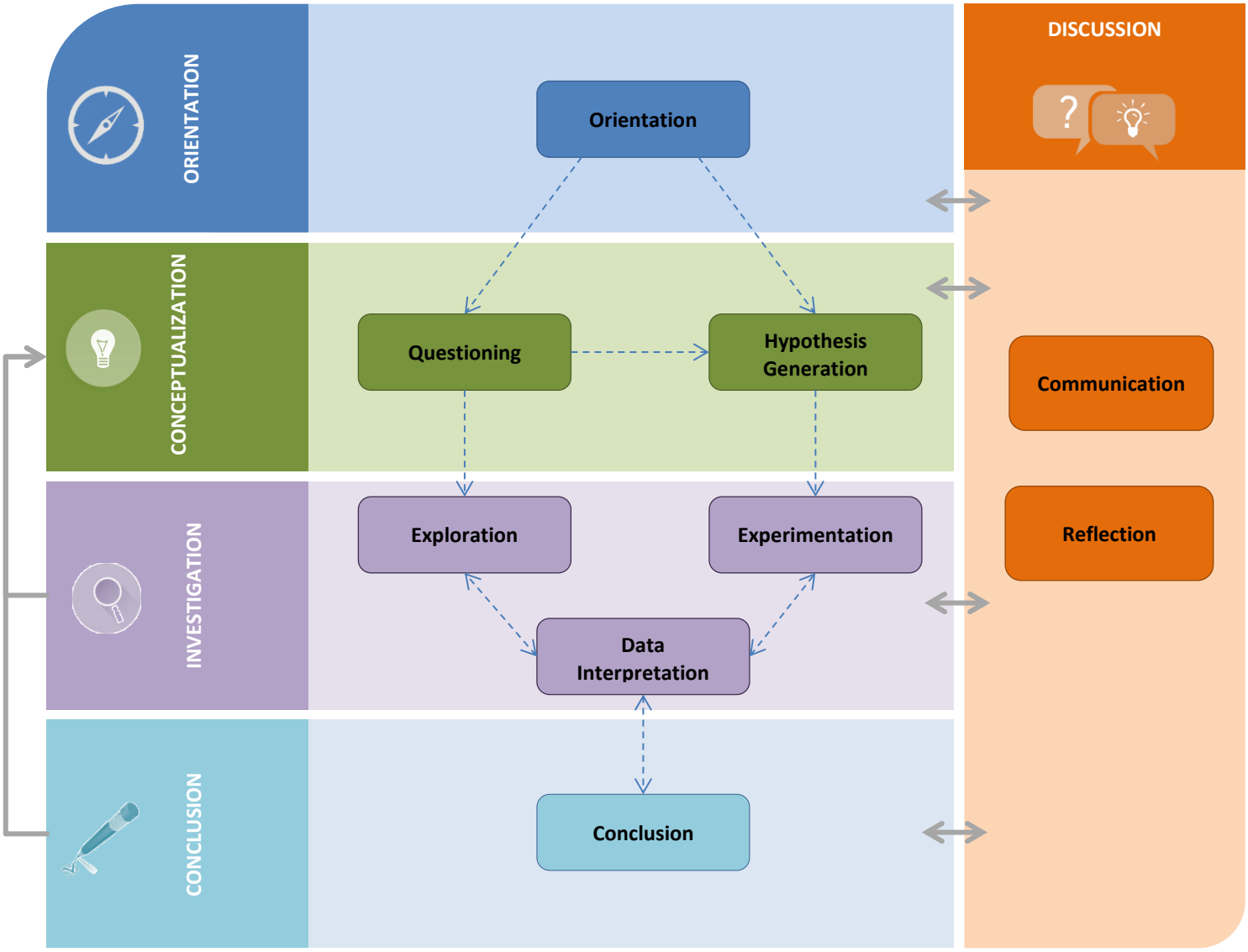
Through inquiry, students are able to further understand and grasp the concept of RRI. Scientific inquiry leads students to question everything around them, make hypotheses, and evaluate their results and the impact these have in society and education. It is, therefore, safe to assume that inquiry is the instrument, the process through which students, and citizens in general, reach responsible research and innovation and are able to make more informed and well-researched scientific decisions that lead to the scientists of the future and to future advancements.

3. Exploring Inquiry in Depth

As you have probably realized so far, inquiry is the main element of the Ark of Inquiry project and it should be promoted at every point during the lesson in your classroom. In this chapter, we will explore inquiry and its components in depth, providing you with theoretical as well as practical parts of inquiry-based learning and teaching. Let's move on!

What are the phases of Inquiry?

So far, extensive research has been conducted on the process of inquiry-based learning to determine the most suitable steps necessary for its development in the science classroom. The various phases and sub-phases of inquiry-based science education have been identified by Pedaste *et al* (2015) as the most comprehensive framework for this learning process:



- **Orientation phase**: Inquiry begins with this phase which has as its main aim to stimulate curiosity about a topic and provide students with opportunities to define a problem statement. As a teacher, your main aim is to find issues and topics that are relevant to your students.

- **Conceptualization phase**: In this phase, research questions and/or hypotheses are stated. As a teacher, you need to encourage students to define them.
    - *Questioning sub-phase*: If pupils have little or no background concerning the scientific topic chosen they should start with this sub-phase.
    - *Hypothesis Generation sub-phase*: After acquiring experience on the topic, students can move on to the hypothesis generation sub-phase. Alternatively, students who are familiar with the topic can move directly to the hypothesis generation sub-phase, skipping the questioning sub-phase, and formulate hypotheses.

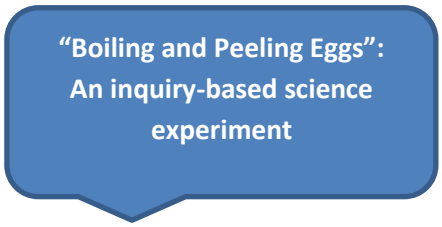
- **Investigation phase**: This phase is mostly based on hands-on activities. It is a process of gathering empirical evidence to answer the research question or hypothesis that was formulated during the previous phase. As a teacher, your role is to monitor and assist students when and where is needed. There are three sub-phases that fall under the phase of Investigation:
    - *Exploration sub-phase*: The process of systematic and planned data generation on the basis of a research question. In this sub-phase, you as teachers, urge students to plan and generate data relevant to the research question.
    - *Experimentation sub-phase*: The process of designing and conducting an experiment in order to test a hypothesis. During this sub-phase, it is time for students to gain hands-on experience by conducting their scientific experiment.
    - *Data Interpretation sub-phase*: The process of making meaning out of collected data and synthesizing new knowledge. Lastly, after having collected the data needed, students need to understand its meaning and gain new knowledge that is based on their experiment.

- **Conclusion phase**: In this phase, research findings from the investigation phase are reported. As a teacher, your role is to encourage pupils to communicate with their peers to present their findings.

- **Discussion phase**: This phase is directly connected to all the previous ones. It consists of communicating findings and reflecting on processes. There are two sub-phases that fall under this category:
    - *Communication sub-phase*: It generates support for scientific research or study, or to inform decision-making, including political and ethical thinking.
    - *Reflection sub-phase*: It aims to raise students' skills in developing creative, scientific problem solving and socio-scientific decision-making abilities.

What does an inquiry-based curriculum look like?

This is where the possibility of putting theory into action comes to fruition! This course provides you with a comprehensive sample lesson plan to help augment your understanding of how to apply inquiry in your science classroom. For the full lesson plan for the "Boiling and Peeling Eggs" experiment, please click on the icon below and/or go to the website below to be able to explore this further at your own convenience!



Website: http://www.arkofinquiry.eu/teachers

What skills and practices are involved during inquiry?

The inquiry learning process starts with the **orientation phase** during which pupils develop an idea about the topic which is introduced by the environment, given by the teachers or defined by himself/herself. Pupils' interest and curiosity for this topic is stimulated, they become more acquainted with the topic and the main variables are identified. The outcome of this phase is a *problem statement* which gives direction for the next phases (Pedaste et al., 2015). Skills that need to be developed or stimulated with your pupils are curiosity, ability to explore a topic, to state problems and to identify variables that matter in their investigation.

During the **conceptualization phase**, pupils should be provided with the opportunity to determine the key concept that will be studied during the inquiry process, driven by either questioning or hypotheses (Pedaste et al., 2015). A pupil with less experience with the topic will first formulate questions based on the problem statement before moving on to hypotheses. Both of these should be based on theoretical justification and contain independent and dependent variables. Pupils learn to raise research questions and identify testable hypotheses. They also learn and practice to make a research plan for their investigation necessary for answering the research questions or test the hypotheses. The outcomes of the conceptualization phase are the research questions and/or hypotheses to be investigated and the research plan to answer these questions/hypotheses.

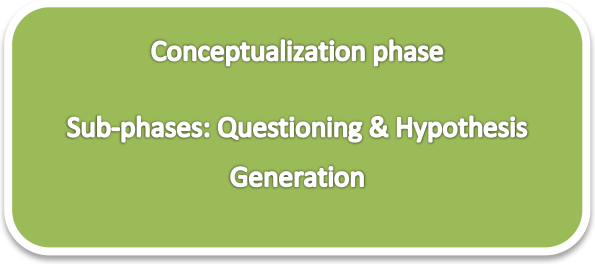
The **investigation phase** follows the conceptualization phase and is the phase where curiosity is turned into action in order to respond to the stated research questions or hypotheses (Scanlon et al., 2011). The first step is to collect data to find answers to the research questions and/or hypotheses. Pupils then move to data analysis by organizing and interpreting their data. During the process of collecting and analyzing, it is important that pupils have the skills to systematically collect data, follow and monitor their research plan and make well-founded changes in this plan if necessary. Pupils learn to search for relevant information, systematically collect relevant data and organize their data in order to help them answer their research questions or test their hypothesis. During data analysis pupils learn to derive meaning out of their collected and organized data and to compare and contrast their findings against each other, as well as against other findings. Gradually, they learn to synthesize findings and recognize patterns in their data that can be formulated into findings.

In the **conclusion phase** the outcomes of the investigation phase are transformed into the main findings of the inquiry process. By relating those findings to their research question(s) and/or hypotheses pupils learn to decide what these conclusions actually mean. During the conclusion phase, pupils learn the ability to infer the answers to their research questions, or arguments for rejecting or supporting their hypothesis from their data (Pedaste et al, 2012). After reaching conclusions and identifying an answer to the research question, the entire inquiry process is critically evaluated in order to determine the solidness of the research findings. That is your primary role as the teacher in the conclusion phase: to teach students how to evaluate their findings and determine their solidness.

On the one hand**,** the **discussion phase** can be seen as an ongoing process related to all other inquiry phases involving communication about and reflection and discussion on the process and outcomes of the inquiry process along the way (Pedaste et al., 2012). On the other hand, when the actual inquiry process is finished it is time to communicate to a wider audience on the relevance, consequences, and ethics of those findings. In this last phase, therefore, special interest is paid to pupils' learning to reflect on, communicate and discuss their inquiry activities and findings to peers, teachers, and society. For the purpose of communication, pupils learn to share research findings by articulating their own understanding of the research answers or hypotheses. They also learn to listen to others sharing their findings or commenting on their own. To communicate well, pupils must be able to reflect on (specific parts of) the inquiry process, and point out the relevance, consequences and ethical issues related to it. They need to be able to receive and provide feedback, and by doing so become part of a community of inquirers that encompasses ongoing discussion fed by scientific research. Besides, communication and reflection upon scientific matters are the main kingpins of Responsible Research and Innovation (RRI), which aims to prepare students for their active and equal participation in science-related affairs within their school, family, and society.

How can teachers support and provide feedback to pupils in inquiry activities?

- Generate interest. This is a great opportunity to present role models, achievements, and perspectives that serve the interests of boys and girls alike.
- Determine pupils' prior knowledge and understanding.
- Divide students into groups. If the groups are mixed gender-wise, both sexes tend to benefit from the learning environment.
- Prompt pupils to create concept maps and elicit ideas.
- Provide enough time for the students to think the problem.
- Make sure that students can describe the problem in their own words and keep in mind that perspectives of the two sexes may differ. Both sides should be encouraged to promote equality in the science classroom.



Questioning	Hypothesis Generation
▪ Assist students in formulating their own research questions by using the following question as a guide: **"Does the… affect the…?"**	▪ Distinguish between Hypothesis and Prediction ▪ After students formulate their questions, ask them to write two columns; the left one should include the question and the right one should include an explanation of how they would answer it. Gender perspectives may vary, so always encourage both.

Investigation phase

Sub-phases: Exploration, Experimentation & Data Interpretation

Exploration and Experimentation	Data Interpretation
▪ Explain that only one variable is independent while the rest are constants. Based on the research question formulated before, assist students by telling them that the variable before the verb "affect" is the independent one, and the one after it, the constant ▪ Check their understanding by providing one example yourself ▪ Assist students with planning and executing by asking them questions during the experiment ▪ Explain to students the Predict-Observe-Explain Cycle (POE) which is another instructional technique to support pupils engagement with inquiry ▪ Advise students to organize their data in graphs, tables, etc.	Guide students towards interpretation of their data by applying the following questions: ▪ **"Did you collect the *correct* data for your question?"** ▪ **"Did you collect *enough* data for your question?"**

Conclusion phase

- Assist students with reaching their conclusion and seeing whether their hypotheses are correct.
- Distinguish between **Claims**—supported by the evidence they have gathered—and **Explanations**—attempts to explain why or generalize from the specific claims.

Discussion phase

Sub-phases: Communication & Reflection

Communication	Reflection
▪ **Encourage the exchange of ideas to promote collaboration within the class**	▪ Encourage peer feedback which will benefit all the students as the perspectives and views on science may vary. This may be especially true between the two genders and, therefore, both sides should be intermingled and supported

The integration of Responsible Research and Innovation (RRI) is amply demonstrated in the discussion phase of inquiry-based education. As the main elements of RRI are communication and dialogue, you, as teachers, should encourage students to actively participate in communicating their results with their peers and reflecting upon them. Reflecting real-life situations where communication on scientific matters occurs, will prepare students for their further participation in science-related topics in society and education.

4. Conclusion

Test Your Knowledge

Congratulations! You just finished the course! We hope you enjoyed it and learned a lot. As a teacher, you know the importance of assessment, so why don't you follow the link below and test your knowledge? If you get 100% right in the online version (you can take the exam multiple times), you will be awarded a certificate as having completed the course.

Online version:
https://www.qzzr.com/quiz/2e606727-d61f-4112-b8e6-af83bc2ae6ba/fi9xdWl6emVzLzExNDg2MQ

1) What is the **main** goal of the Ark of Inquiry project?
    a) To create a "new science classroom" where students would get hands-on experience in science
    b) To conduct research on what inquiry is for the further development of this theory
    c) To give more details on the involvement of the EU in science-based education

2) What are the main parameters of Responsible Research and Innovation (RRI)?
    a) Involvement of citizens in research and technology-related decisions and learning new research methods
    b) Evaluation of technology in society and education, involvement of citizens, gender equality, communication and dialogue
    c) Conducting scientific experiments to test general science-related hypotheses

3) How is inquiry defined in the Ark of Inquiry project?
    a) Asking questions
    b) Asking questions, making discoveries, and testing
    c) Understanding scientific theory

4) What is the correct order of the five phases of inquiry as identified by Pedaste *et al* (2015)?
    a) Orientation, conceptualization, investigation, conclusion, discussion
    b) Orientation, hypothesis generation, investigation, communication, discussion
    c) Conceptualization, questioning, investigation, conclusion, reflection

5) How can **gender equality** be supported and encouraged through inquiry-based learning activities?
    a) Teachers ask students to perform experiments that are mostly suited to girls' needs
    b) Teachers present role models and achievements that are paramount to both genders
    c) Teachers encourage boys and girls to separate during groups activities so that their views are the same in each group

6) What are some of the ways that teachers can support students during inquiry activities and more specifically in the **Orientation phase**?
    a) Advise students to organize their data in graphs and tables and prepare for a new experiment
    b) Assist students by discussing the independent and dependent variables and assisting them with formulating a hypothesis
    c) Generate interest, determine prior knowledge, and make sure that students can describe the problem in their own words

7) How can students navigate through the sub-phases of **Conceptualization**?
    a) It is mandatory for students to move from Questioning to Hypothesis Generation despite their level of experience with the topic
    b) Students with limited experience can go from Questioning to Hypothesis, while students with more experience can skip Questioning altogether
    c) All students, despite their level of experience with the topic, have to move from Hypothesis Generation to Questioning

8) What step is undertaken during the **Investigation phase**?
    a) Students analyze the theoretical background of the scientific topic given
    b) Students organize their data into graphs and tables
    c) Students get hands-on experience with a scientific experiment and gather empirical data by answering research questions

9) What is the primary role of the teacher during the **Conclusion phase**?
    a) To teach students to evaluate their work and determine the solidness of their findings
    b) To encourage students to reflect on their work
    c) To allow students enough time to conduct a new experiment

10) What happens during the two sub-phases of the **Discussion phase**?
    a) Students collect and organize their data
    b) Students decide whether their experiment is correct; if it is not, then they conduct another one
    c) Students are supported towards scientific research and decision-making, along with developing their creative and problem-solving skills

To find out the correct answers, please go to the last page of this booklet[i]!

Your Feedback is Valuable to Us

Thank you for completing the course! This is your first step towards using inquiry based education in your science classroom. Your feedback is valuable to us and we would like to know your opinion on the course itself. Please let us know your thoughts by completing the very short questionnaire at the following link:

Feedback form:
https://docs.google.com/forms/d/1ClfMFxb0-rSiW-63p_rNYjSPjFJ8zOYDwlzief0Sv4s/viewform

5. Join the Ark of Inquiry Community

One of the main objectives of the Ark of Inquiry project is to create a community that maintains and expands on the project. We would like you to be part of that community!

Please take 1-2 minutes to fill in this form **here** (http://www.bit.ly/AoI_Community) and we look forward to seeing you on board the Ark of Inquiry project!

Also, follow us on Facebook, Twitter and LinkedIn!

6. Credits

Design and Development Credits

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References

Pedaste, M., Mäeots, M., Leijen, Ä., & Sarapuu, T. (2012). *Improving students' inquiry skills through reflection and self-regulation scaffolds*. Technology, Instruction, Cognition and Learning, 9(1-2), p.81-95.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A., Kamp, E. T., Manoli, C. C., Zacharia, Z., & Tsourlidaki, E. (2015). *Phases of inquiry-based learning: Definitions and the inquiry cycle*. Educational research review, 14, p.47-61.

Scanlon, E., Anastopoulou, S., Kerawalla, L., & Mulholland, P. (2011). *How technology resources can be used to represent personal inquiry and support students' understanding of it across contexts*. Journal of Computer Assisted Learning, 27(6), p.516-529.

[i] *Test your knowledge* answers: 1) A 2) B 3) B 4) A 5) B 6) C 7) B 8) C 9) A 10) C